M1
METROLOGY

MICOM, Inc.

Access

OPERATING and SERVICE MANUAL

M1
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model 8300/8300W

FLUTTER METER

SERIALS PREFIXED

067——

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MICOM, INC. 855 COMMERCIAL STREET, PALO ALTO, CALIFORNIA, U.S.A. 94303

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855 Commercial Street Palo Alto, California, U.S.A.

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MICOM MODEL 8300/8300W FLUTTER METER SPECIFICATIONS

TEST SIGNAL INPUT

Frequencies: 1.69kHz, 3.38kHz, 6.75kHz, 13.5kHz, 27kHz, 54.0kHz, 108kHz and 216kHz
Input level: 10mV to 2V rms
Input Impedance: 100 kilohms shunted by approximately 50pF unbalanced
Limiting tolerability to dropouts: 60dB from 1V input level for dropouts of less than 10 msec duration
Maximum acceptable frequency deviations: ± 10% (Range over which zero set may be adjusted to center drift meter)

SIGNAL LEVEL MONITOR

Restores meters to zero when signal above or below range of proper operation. Lamp indications of signal level.
Low Level Threshold: 10mV rms
High Level Threshold: 2V rms

DRIFT MEASUREMENTS

Frequency Range: DC to .7Hz ± 20% FAST
DC to .2Hz ± 20% SLOW
Indication Mode: + or – % frequency deviation with "0" center meter
Test Ranges: ±.03, 0.1, 0.3, 1, 3, and 10% full scale
Meter Accuracy: ± 5% full scale at DC

FLUTTER MEASUREMENTS

Frequency Ranges:
0.5 to 313 Hz with 1.69 kHz or higher Test Frequency
0.5 to 625 Hz with 3.38 kHz or higher Test Frequency
0.5 to 1.25 kHz with 6.75 kHz or higher Test Frequency
0.5 to 2.50 kHz with 13.5 kHz or higher Test Frequency
0.5 to 5.00 kHz with 27.0 kHz or higher Test Frequency
0.5 to 10.0 kHz with 54.0 kHz or higher Test Frequency
0.5 to 20.0 kHz with 108 kHz or higher Test Frequency
Indication Modes: Peak-to-peak to 1 σ limit (random peaks occurring less than 32% of the time excluded)
Peak-to-peak to 2 σ limit (random peaks occurring less than 5% of the time excluded)
Peak-to-eak to 3 σ limit (random peaks occurring less than 0.3% of the time excluded)
Test Ranges: .01, .03, 0.1, 0.3, 1, 3, and 10% full scale
Meter Accuracy: ± 5% full scale at 100Hz.

INTERNAL TEST OSCILLATOR

Test Frequencies: 1.69kHz, 3.38kHz, 6.75kHz, 13.5kHz, 27kHz, 54.0kHz, 108kHz and 216kHz ± .01%
Output Voltage: 1V rms ± 1dB
Source Impedance: < 20 ohms, unbalanced, into loads above 300 ohms

Specification subject to change without notice

Made in U.S.A.

DEMODULATOR OUTPUTS FOR ANALYSIS

DRIFT DEMODULATOR OUTPUT

Frequency Range: DC to 30Hz ± 20% -3dB, asymtotic to 18dB/octave above 60Hz; -3dB at .7Hz ± 20% in FAST and SLOW positions
Output Voltage: + or – 0.1V for full scale meter indication
Source Impedance: 1 kilohm unbalanced
Accuracy: ± 2% full scale at DC; +0, <-1dB from DC to 10Hz

FLUTTER DEMODULATOR OUTPUT

Frequency Ranges: From .2Hz ± 20% to 313Hz, 625Hz, 1.25kHz, 2.5kHz, 5kHz, 10kHz, and 20kHz, ± 5% at -3dB
Response ± 1dB from 1Hz to 80% BW, falling >6dB/octave below .2Hz and >30dB/octave above 1.8 x BW.
Output Voltage: 0.1V peak-to-peak for full scale meter indication
Source Impedance: <100ohms, unbalanced
Accuracy: ± 2% at 100Hz, ± 5% from 2Hz to 60% BW

EQUIVALENT INTERNAL INSTRUMENT NOISE

Less than .001% (10ppm) rms with pure sine wave input above 100mV rms at 108 or 216kHz and 20kHz flutter bandwidth

ANALYZER EXTERNAL INPUT (to Wave Analyzer)

Frequency: From .5Hz to 20kHz
Impedance: 2.5 kilohms, unbalanced
Sensitivity: 1mV, 3mV, 10mV, 30mV, 100mV, 300mV and 1V full scale

EXTERNAL FILTER INPUT

Impedance: 30 kilohms
Source used: Demod output (has 1.2V peak-to-peak level full scale in this mode)

8300-W WAVE ANALYZER

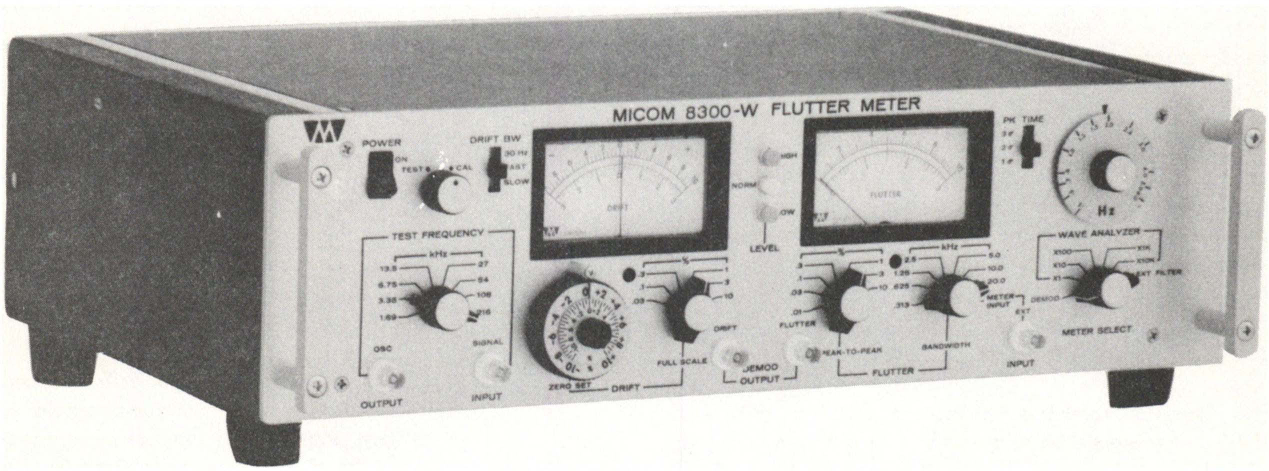
Frequency Range: .5 to 20kHz continuously tunable in 5 decade bands
Accuracy of frequency calibration: ± 5%
Frequency Response: ± 1.5dB over entire tuning range
Bandwidth: 3dB down at + and – 5% of selected frequency; >20dB down at 1/2 and 2 times selected frequency
Indication: ± % peak-to-peak on Flutter Indicator

GENERAL

Power: 115 or 230V, ±10%; 50/60Hz; 25 watts
Front Panel Dimensions: 5.25" x 19" wide
Cabinet Dimensions: 6.25" x 19" x 13" overall
Ambient temperature range: 0 – 60°C
Bench or Rack mount
Net Weight: 20 lbs. – Shipping Weight: 26 lbs.

SECTION I

GENERAL INFORMATION



MODEL 8300/8300W FLUTTERMETER

1-1 DESCRIPTION

1-1.1 The MICOM 8300 and 8300-W flutter meters are solid state instruments for measuring and indicating long-term variations (drift) and instantaneous variations (flutter) in the speed of instrumentation magnetic tape recorders and reproducers. "Flutter" and "drift" are terms describing the amount by which the time scale of the signal reproduced from such recorders fails to duplicate the time scale of the originally recorded signals. They are measured by recording and/or reproducing a constant frequency tone: the error in the time scale of the reproduced signal then appears as frequency modulation of this tone. This frequency modulation is measured with a Flutter Meter, which is essentially a stable calibrated FM demodulator.

1-1.2 The only standard procedures specified for the measurement of flutter in instrumentation-type recorders are contained in the "Telemetry Standards of the Telemetry Working Group of the Inter-Range Instrumentation Group of the Range Commanders Council", commonly referred to as the IRIG Standards, document 106-66. The flutter measurement methods called out in this document do not refer to the use of a flutter meter, because at the time the document was prepared, no flutter meter of adequate performance was available. The IRIG Standards, therefore, call out a selection of conventional elementary pieces of equipment (discriminators, oscillators, etc.) with which flutter measurements can be made. The MICOM flutter meters for instrumentation use, the Models 8200 and 8300 are single instruments which implement the measurement of flutter and drift to the IRIG Standards in a simple and precise way.

1-1.3 The MICOM Model 8200 and 8200-W are general purpose flutter meters for use with tape speeds and bandwidths typical in instrumentation recording. The MICOM Model 8300 and 8300-W flutter meters are designed to make measurements only at the frequencies and bandwidths called out in the IRIG Standards. IRIG-type measurements can be made with either instrument.

1-2 OPTIONS AVAILABLE

1-2.1 The MICOM 8300-W contains an integral wave analyzer tunable over a frequency range of from .5 Hz to 60 kHz in 5 decade ranges. (The flutter demodulator output is limited to 20 kHz.) When using the wave analyzer, the flutter indicator shows only the flutter components of the frequency tuned on the dial. The selectivity of the analyzer is approximately one tenth octave, equivalent to that of an RLC tuned circuit with a Q of 10. With the aid of the wave analyzer, and a knowledge of the mechanical design of the machine under test, the specific parts of the mechanism contributing to the flutter may be more easily identified.

1-3 EFFECTS AND DESCRIPTION OF FLUTTER

1-3.1 The terminology by which flutter is described draws heavily on the audio engineering field since the effects of flutter were first observed in this field and were hence

originally described entirely in audible terms. Flutter itself is a term which implies the audible sound of a speed variation and, hence, of frequency modulation at a fairly high frequency. For example, speed variation at frequencies from zero to about 1 Hz appears as drifts of pitch when listened to as an audio signal and is therefore usually referred to as "drift"; speed variation of frequencies between about 1 and 5 to 8 Hz are audibly heard as "wow" and are often so described; above 50 to 200 Hz, the ear hears the speed-variation sidebands as noise, and flutter frequencies in this region are often referred to as "modulation noise" added to the signal. With speed variation at rates in the region from 8 to 50 Hz, the audio tone quality is modified, causing a roughening of the tone which is not audible as a pitch change per se. This latter roughening is usually considered to be "true flutter". This audio terminology has carried over to the instrumentation field where no audible signals are encountered. It is noted here as an explanation of an otherwise rather mysterious terminology.

1-4 FLUTTER MEASUREMENT TECHNIQUES

1-4.1 No specific standards for allowable flutter have been set by IRIG. There are two reasons for this omission. First, so many different recording/reproducting modes are used which react in widely different ways to the presence of flutter in the reproduced signal that a very complex set of standards would have to be set; second, compensation for flutter is so widely used that the actual significance of flutter is often concealed in the overall equipment performance. It is possible to base objective flutter standards for audio on the results of a series of detailed subjective reaction tests designed to determine the detectability and objectional qualities of flutter. No such situation can be expected to exist for instrumentation recording.

1-4.2 IRIG FLUTTER MEASUREMENTS

1-4.3 Because no instrument such as the MICOM Model 8300 existed in March, 1966 when the current version of the IRIG Standards were issued, two indirect methods of obtaining the results produced by the MICOM Model 8300 are described in IRIG Document 106-66. Edited extracts from the pertinent paragraphs on suggested flutter measurements are included below:

> 5.6.3.2.3 Flutter Two methods of measuring flutter are proposed. Each method calls for the use of an FM discriminator such as may be supplied by the manufacturer in his equipment as an FM reproduce amplifier or such as those used in FM/FM telemetry. This method may not eliminate the apparent flutter caused by amplitude modulation noise, signal dropouts or preamplifier random noise. If this method is to be used, (paragraph 5.6.3.2.3 (b) and Steps a, b, c, d and e of paragraph 5.6.3.2.3 (c) (6) will apply). The peak-to-peak flutter shall be considered to include all the flutter data appearing on the camera record except random peaks and drift components below 0.2 c/s.

The second test procedure is designed to measure tape motion variations or flutter. To the greatest extent possible, it eliminates apparent flutter caused by instrumentation, amplitude modulation noise on a test signal and dropouts in signal.

(a) Equipment for the measurement of flutter is shown in Figure 12.

(b) Degaussed virgin tape specified by the manufacturer shall be used.

(c) The discriminator used for flutter measurements shall meet the following performance requirements:

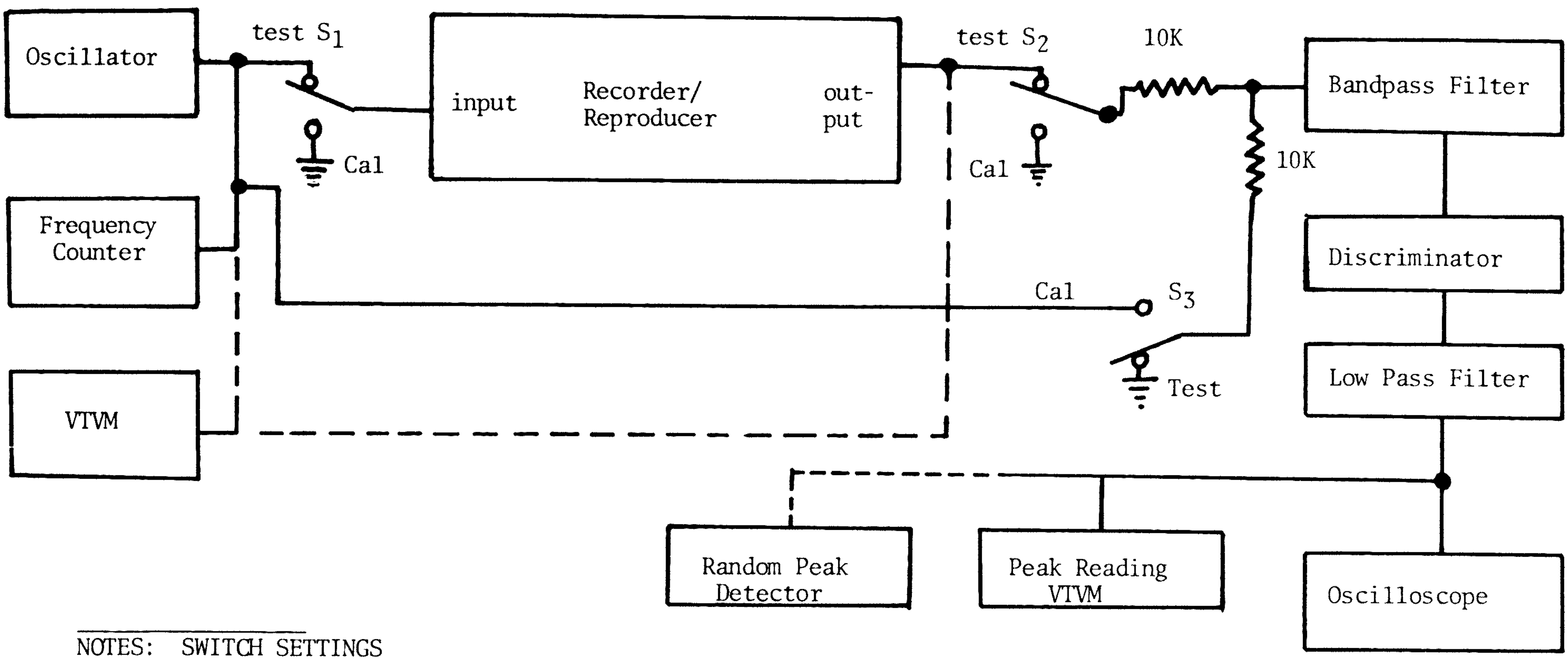
1. The discriminator output noise caused by 30 percent amplitude modulation of the reference carrier by any single frequency from dc up to the flutter upper band limit should be less than 10 percent p-p of the peak-to-peak specification flutter signal.

2. The discriminator output noise caused by a linear mixing of the output noise of the tape system and a stable reference carrier of the same level as would be derived from the system should be less than 5 percent p-p of the p-p specification flutter signal. The system setup is shown in Figure 12 with the switch in the disciminator test position. The tape system will be in the record mode (bias on) with input shorted.

3. Band-Pass Filter A band-pass filter may be used to eliminate system noise. However, the 3-db bandwidth of the filter cannot be less than 2 times the flutter bandwidth being measured and must be symmetrical about the reference carrier frequency used.

4. Low-Pass Output Filter The low-pass output filter may have either a flat or Gaussian response shape. The flat filter system (including discriminator) shall be down no more than 3 db at the upper flutter frequency being measured. The Gaussian filter system shall be down no more than 6 db at the upper flutter frequency being measured.

5. In the event that the discriminator used in the test fails to meet paragraphs 5.6.3.2.3 (c) (1) and 5.6.3.2.3 (c) (2) when using the appropriate filter in paragraphs 5.6.3.2.3 (c) (3) and 5.6.3.2.3 (c) (4), the peak-to-peak value of the noise obtained in paragraphs 5.6.3.2.3 (c) (1) and 5.6.3.2.3 (c) (2) shall be subtracted from the peak-to-peak flutter measurements. The permissible correction shall not exceed 25 percent of the flutter specification.

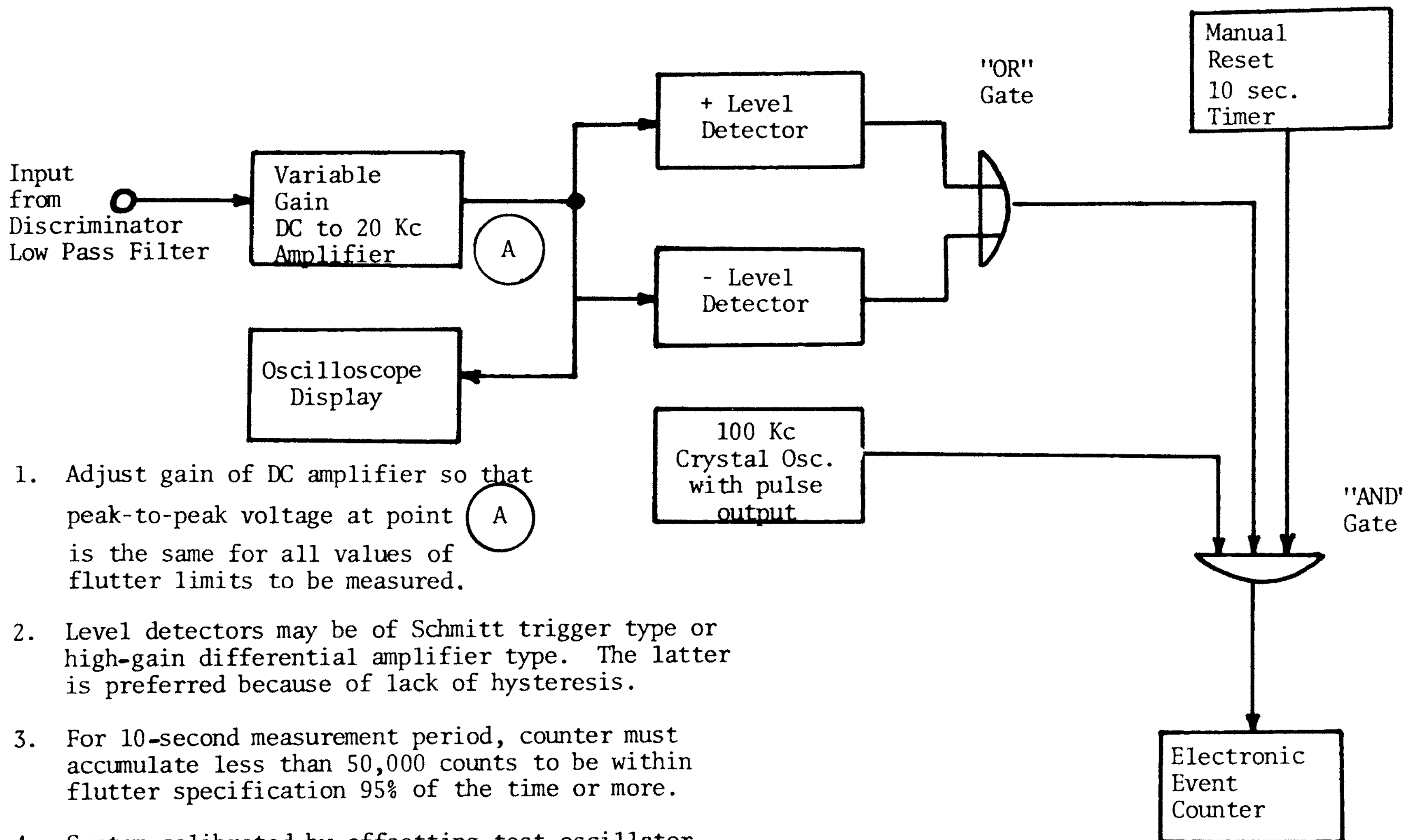


NOTES: SWITCH SETTINGS

	Discriminator Amplitude Calibration	Discriminator Noise Calibration	Flutter Test
S_1	CAL	CAL	Test
S_2	CAL	Test	Test
S_3	CAL	CAL	Test

FIGURE 12 FLUTTER TEST

FIGURE I-I IRIG FLUTTER TEST



1. Adjust gain of DC amplifier so that peak-to-peak voltage at point (A) is the same for all values of flutter limits to be measured.

2. Level detectors may be of Schmitt trigger type or high-gain differential amplifier type. The latter is preferred because of lack of hysteresis.

3. For 10-second measurement period, counter must accumulate less than 50,000 counts to be within flutter specification 95% of the time or more.

4. System calibrated by offsetting test oscillator input to Discriminator to frequency of maximum allowable flutter deviation. Set gain of DC amplifier so that counter just begins to trigger on maximum allowable deviation.

5. Variable gain DC amplifier must have capability to produce gains of less than one as well as gains greater than one.

FIGURE 13 BLOCK DIAGRAM, RANDOM PEAK DETECTOR FOR DIGITIZED FLUTTER MEASUREMENT

FIGURE I-2 IRIG DIGITIZED FLUTTER TEST

Table XIII

FILTER CHARACTERISTICS FOR FLUTTER MEASUREMENT

Tape Speed (ips)	Minimum Bandwidth of Band-Pass Filter at 3 db points (kc/s)	Passband of the Low-Pass Filter*(c/s)
1-7/8	0.625	0.2 to 313
3-3/4	1.250	0.2 to 625
7-1/2	2.500	0.2 to 1,250
15	5.000	0.2 to 2,500
30	10.000	0.2 to 5,000
60	20.000	0.2 to 10,000
120	20.000	0.2 to 10,000

* No more than 3 db for flat filter
No more than 6 db for Gaussian filter

6. Any center frequency may be used providing it meets paragraphs 5.6.3.2.3 (c) (1) and 5.6.3.2.3 (c) (2) and is at least five times the maximum flutter frequency.

Steps:

a. Adjust the test oscillator and the discriminator to the frequencies suitable to the machine speeds. This adjustment shall be capable of an accuracy of 0.01 percent of the carrier, or better.

b. Calibrate the oscilloscope such that full-scale deflection is equal to 1.0 percent of the oscillator frequency. Adjust the horizontal time to 1 second per centimeter.

c. Degauss the tape and place on the transport. Place the machine in record mode and select the tape speed to be measured.

d. Turn equipment from calibrate condition to test condition and adjust input signal level above normal, approaching saturation (suggested value +13 db relative to normal record level). Record test signals on the two outside tracks and the center track. Observe the flutter display from each track on the oscilloscope. A 3-minute minimum recording at the beginning, middle and end of the reel shall be made. (See paragraph 5.6.3.1)

e. The flutter as displayed on the oscilloscope camera, at the beginning, mid and end of reel may be photographed. Each photograph will cover a 10-second period.

f. The peak-to-peak flutter shall be considered to include all the flutter data appearing on the camera record, except random peaks and drift components below 0.2 c/s. The 2 σ limit on flutter shall be equal to the specification limit which means the random peaks will not exceed the specification more than 5.0 percent of the time. A direct reading instrument to measure this condition is described in Figure 13. If the random noise exceeds the specification 5.0 percent of the time, the cause of the noise must be determined and eliminated before the test can continue.

1-4.4 Figures 12 and 13 of the IRIG document are reproduced here to indicate the technique which has heretofore been used for determining flutter. The MICOM Model 8300 flutter meter was designed primarily to avoid the complex methods involved in both these test procedures. In addition, an objective in the design of the instrument was to eliminate the very awkward method of Figure 13 for obtaining the true 2 σ flutter value as the only alternative to the rather indefinite measurement provided by visual interpretation of the Figure 12 test procedure.

1-4.5 The Model 8300 provides flutter bandwidths which are from twice those specified in the IRIG table. This is true both of the bandpass filters and the output low-pass filters. With the particular objective of avoiding the oscillator-counter technique of the IRIG Figure 13 for determining the 2 σ limit, the Model 8300 contains a circuit which provides a meter reading in direct terms of the 1 σ, 2 σ or 3 σ limit on a continuous basis. This special measuring circuit is described in detail under THEORY OF OPERATION' It operates by balancing a supply of charge to a capacitor, proportioned to the length of time the flutter exceeds a given threshold, against a steady rate of drain of charge from it. The potential across the capacitor is in turn used to vary the flutter threshold. The capacitor potential reaches equilibrium for a flutter value which is exceeded a given fraction of the time, as determined by the circuit constants.

1-4.6 Whereas the IRIG procedure recommends that a value of flutter be measured which is exceeded only 5 percent of the time, the MICOM Model 8300 also provides an indication of flutter value which is exceeded 0.3 percent of the time (3 σ limit) and 32 percent of the time (1 σ limit, essentially twice the rms value of Gaussian noise).

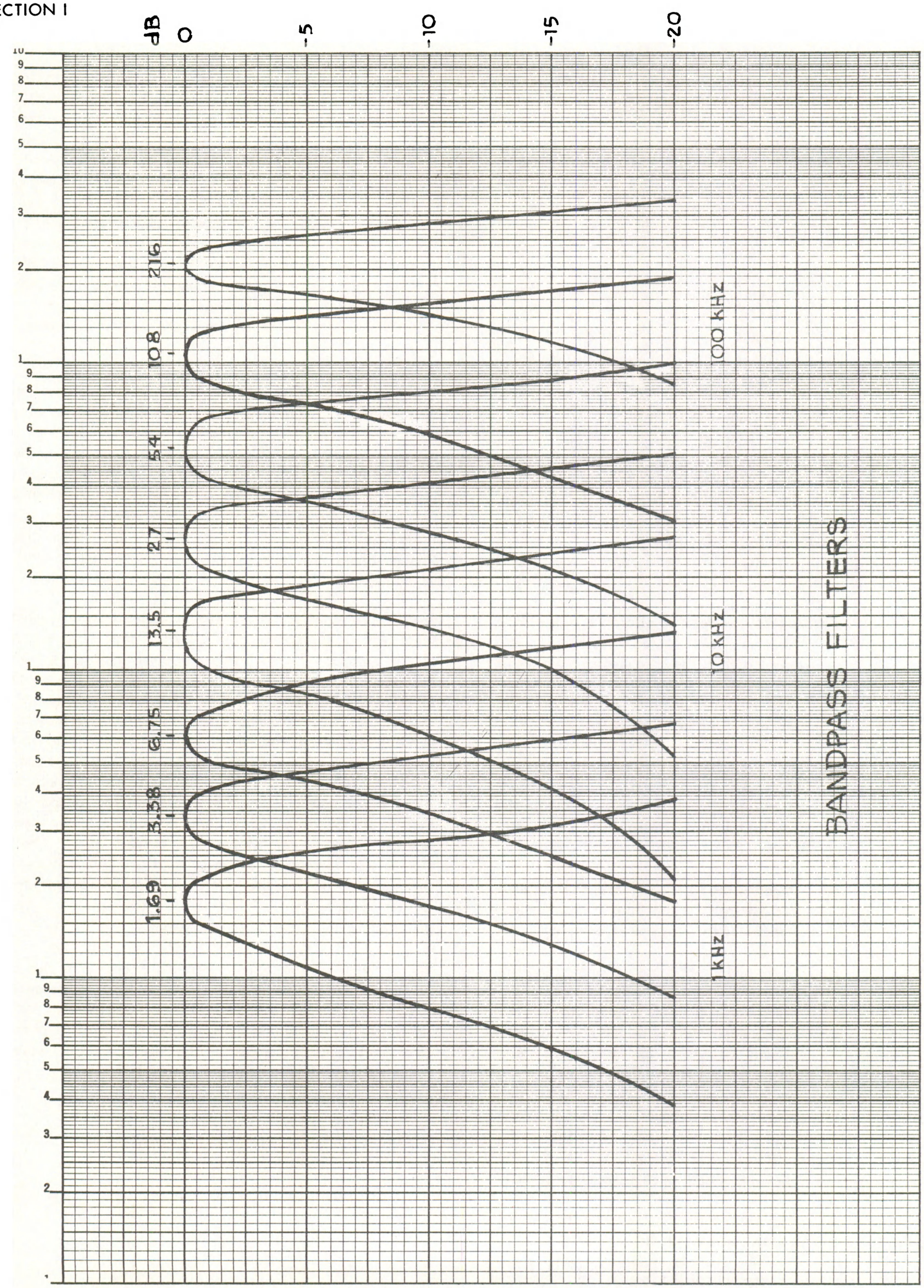


FIGURE 1-3 BANDPASS FILTERS

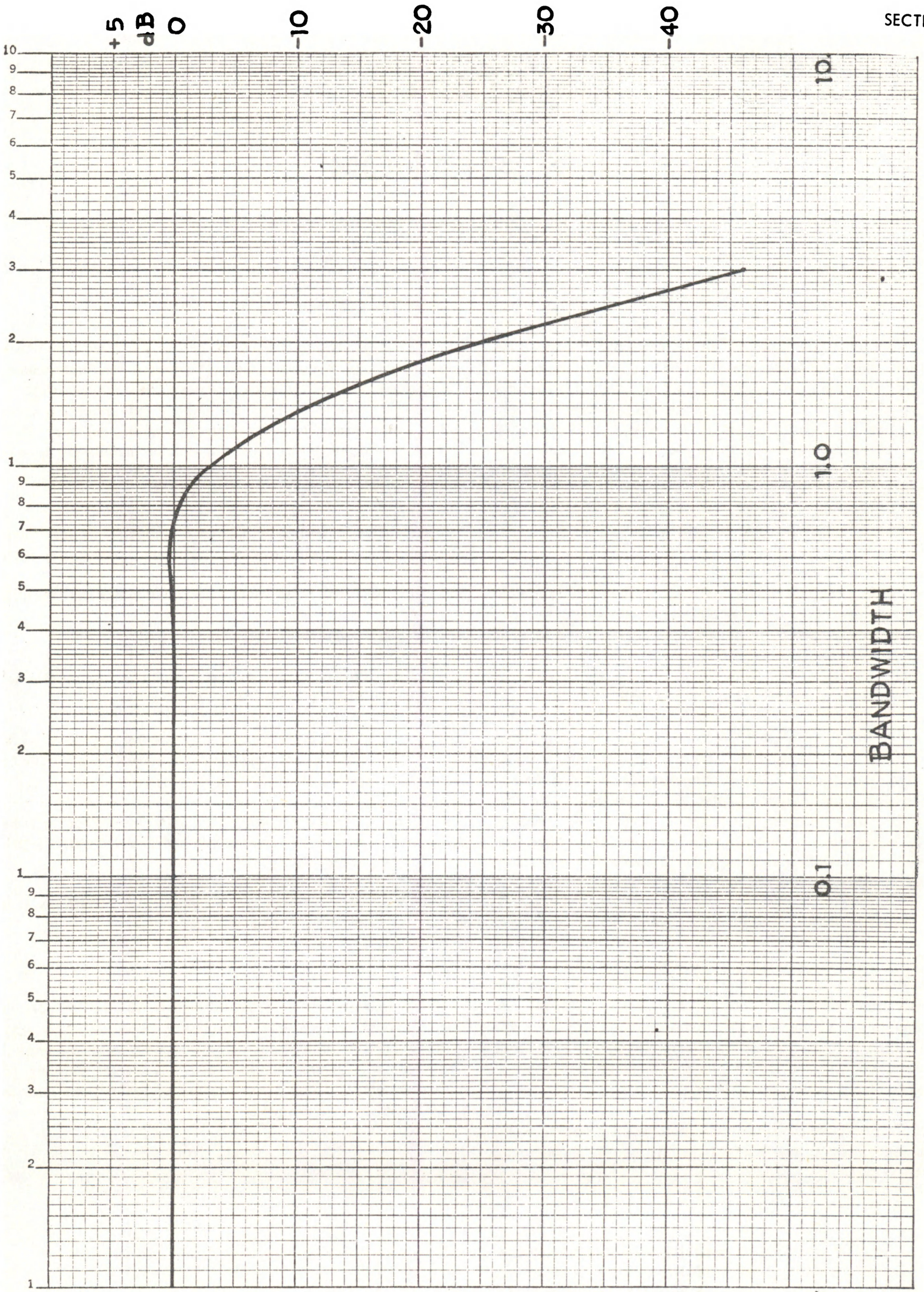


FIGURE 1-4 LOWPASS FILTERS

SECTION II

INSTALLATION

2-1 INSPECTION

2-1.1 This instrument was carefully inspected both mechanically and electrically before shipment. It should be physically free of mars or scratches and in perfect electrical order upon receipt. To confirm this, the instrument should be inspected for physical damage in transit. Also check for supplied accessories, and test the electrical performance of the instrument. If there is damage or deficiency, see the warranty in Section 1.

2-1.2 CLAIM FOR DAMAGE IN SHIPMENT

2-1.3 Your instrument should be inspected and tested as soon as it is received. The instrument is insured for safe delivery. If the instrument is damaged in any way or fails to operate properly, file a claim with the carrier or, if insured separately, with the insurance company.

2-2 POWER REQUIREMENTS

2-2.1 The Models 8300 and 8300-W will operate from either 115 or 230V ac, 50 - 60 Hz. The instruments can be easily converted from 115 to 230 volt operation by changing the position of the slide switch, located on rear panel, so that the designation appearing on the switch matches the nominal voltage of the power source. A 1/2 ampere, blow-blow fuse is used for 115-volt operation; a 1/4 ampere slow-blow fuse is used for 230-volt operation.

2-3 THREE CONDUCTOR POWER CABLE

2-3.1 To protect operating personnel, the National Electrical Manufacturers' Association (NEMA) recommends that the instrument panel and cabinet be grounded. All MICOM instruments are equipped with a three-conductor power cable which, when plugged into an appropriate receptacle, grounds the instrument. The offset pin on the power cable three-prong connector is the ground wire.

2-3.2 To preserve the protection feature when operating the instrument from a two-contact outlet, use a three-prong adapter to ground.

2-4 INSTALLATION

2-4.1 The 8300 and 8300-W are fully transistorized; therefore, no special cooling is required. However, the instruments should not be operated where the ambient temperature exceeds 65°C (150°F).

2-5 RACK/BENCH INSTALLATION

2-5.1 The 8300 and 8300-W are shipped as bench type instruments with rubber feet. To mount the instrument in a standard 19" relay rack, remove the side castings. Two 10-32 screws in each handle and one side mounting screw to the rear attach each casting to the instrument. Use the screws in the handles to fasten the instrument in a rack.

2-6 REPACKAGING FOR SHIPMENT

2-6.1 The following is a general guide for repackaging for shipment. If you have any questions, contact the factory.

a. Place instrument in original container if available.

If original container is not used:

b. Wrap instrument in heavy paper or plastic before placing in an inner container.

c. Use plenty of packing material around all sides of instrument and protect meter faces with cardboard strips.

d. Place instrument and inner container in a heavy carton or wooden box and seal with strong tape or metal bands.

e. Mark shipping container with "Delicate Instrument", "Fragile", etc.

NOTE

If the instrument is to be shipped to MICOM for service or for repair, attach a tag to the instrument identifying the owner and indicate the service or repair to be accomplished; include the model number and full serial number of the instrument. In any correspondence, identify the instrument by model and serial number.

NOTES

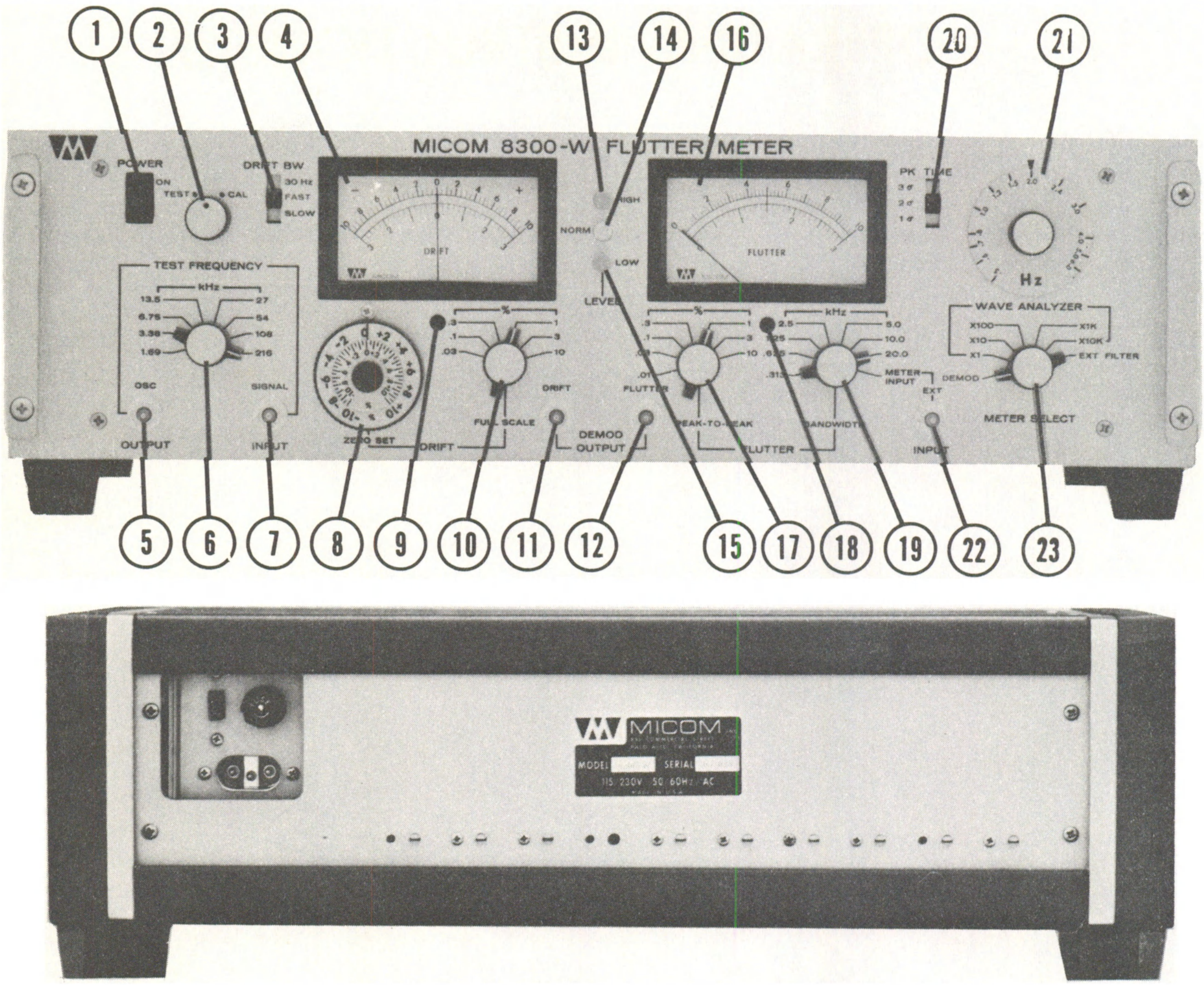


FIGURE 3-1

1. POWER switch turns instrument ac power on. HIGH, NORMAL or LOW level lamp will glow when instrument is on.

2. TEST/CAL switch permits setting zero on drift meter in CAL position and in TEST position, then checks that instrument is operating normally, as indicated by full-scale deflection on both DRIFT and FLUTTER meters.

3. DRIFT BW switch selects bandwidth of drift indicator and DRIFT DEMOD OUTPUT. In 30 Hz position sets bandwidth of DRIFT DEMOD OUTPUT appearing at connector at 30 Hz (meter indication not dependable). FAST position gives .7 Hz and SLOW position .2 Hz bandwidth for DRIFT meter indication and DRIFT DEMOD OUTPUT.

4. DRIFT meter indicates percentage of frequency difference between input signal and that set by ZERO SET control.

5. TEST OSC OUTPUT provides stable test oscillator output at frequency indicated on TEST FREQUENCY selector.

6. TEST FREQUENCY selector sets operating frequency of instrument and frequency of test signal supplied to TEST OSC OUTPUT connector.

7. SIGNAL INPUT connector receives reproducer output signals for flutter and drift measurement.

FIGURE 3 - 1 FRONT AND REAR PANEL CONTROLS

SECTION III

OPERATING INSTRUCTIONS

3-1 INTRODUCTION

3-1.1 The Models 8300 and 8300-W flutter meters will measure both reproduced long-term frequency error and flutter in instrumentation tape recorders. Drift in speed at rates from dc up to .7 Hz is indicated on the DRIFT meter. Drift of from ± .03% to ±10% full-scale may be accommodated. Flutter content of recorder output over the frequency

8. DRIFT ZERO SET dial controls the frequency at which the DRIFT METER indicates zero. Outer dial changes frequency in 2% increments, inner vernier adjust continuously over ±1.1% range.

9. MECHANICAL ZERO ADJUST mechanically adjusts DRIFT meter to zero with instrument turned off.

10. DRIFT % FULL SCALE switch sets sensitivity of drift indicator from ±.03% full scale to ±10% full-scale.

11. DRIFT DEMOD OUTPUT connector permits connecting the output of the drift demodulator to an oscillograph, oscilloscope or voltmeter, 100 mV for full scale meter indication.

12. FLUTTER DEMOD OUTPUT connector permits connecting output of the flutter amplifier to an oscillograph, oscilloscope, voltmeter or external wave analyzer. 100 mV peak-to-peak for full scale meter indication.

13. HIGH LEVEL lamp glows to indicate that the input level is too high for proper operation.

14. NORMAL LEVEL lamp glows to indicate that the input level is within the range satisfactory for proper operation (normal).

15. LOW LEVEL lamp glows to indicate that the input level is below that required for proper operation.

16. FLUTTER INDICATOR meter indicates percentage of flutter contained in the input signal or the amplitude of the EXT INPUT signal.

17. FLUTTER % PEAK-TO-PEAK switch varies full scale flutter sensitivity from .01% peak-to-peak to 10% peak-to-peak.

18. MECHANICAL ZERO ADJUST mechanically adjusts FLUTTER INDICATOR METER to read zero when the instrument is turned on and the METER SELECT switch is in EXTERNAL INPUT position.

19. FLUTTER BANDWIDTH selector switch permits varying flutter measuring bandwidth of the instrument from 0.313 to 20 kHz, or connects input of flutter-indicating section of instrument to EXT INPUT connector for use as statistical voltmeter or wave analyzer.

20. PK TIME switch permits varying the fraction of total time FLUTTER meter indication is exceeded by input flutter. In 3 σ position, actual flutter exceeds meter indication 0.3% of time, in 2 σ position meter indication is exceeded 5% of time and in 1 σ position meter indication is exceeded 32% of time.

21. Hz (frequency) dial (Model 8300-W only) selects frequency of maximum response of WAVE ANALYZER.

22. EXT INPUT connector permits connecting external signals to flutter-indicating section of instrument. (Usually employed by connecting an external bandpass filter between FLUTTER DEMOD OUTPUT and this connector.)

23. METER SELECT switch permits connecting FLUTTER indicator meter either to FLUTTER DEMOD OUTPUT (normal operation), to the FLUTTER DEMOD OUTPUT through the WAVE ANALYZER for various wave analyzer frequency ranges from 1 to 10 K times the WAVE ANALYZER frequency dial scale, or to the output of an external filter fed in through EXT INPUT connector.

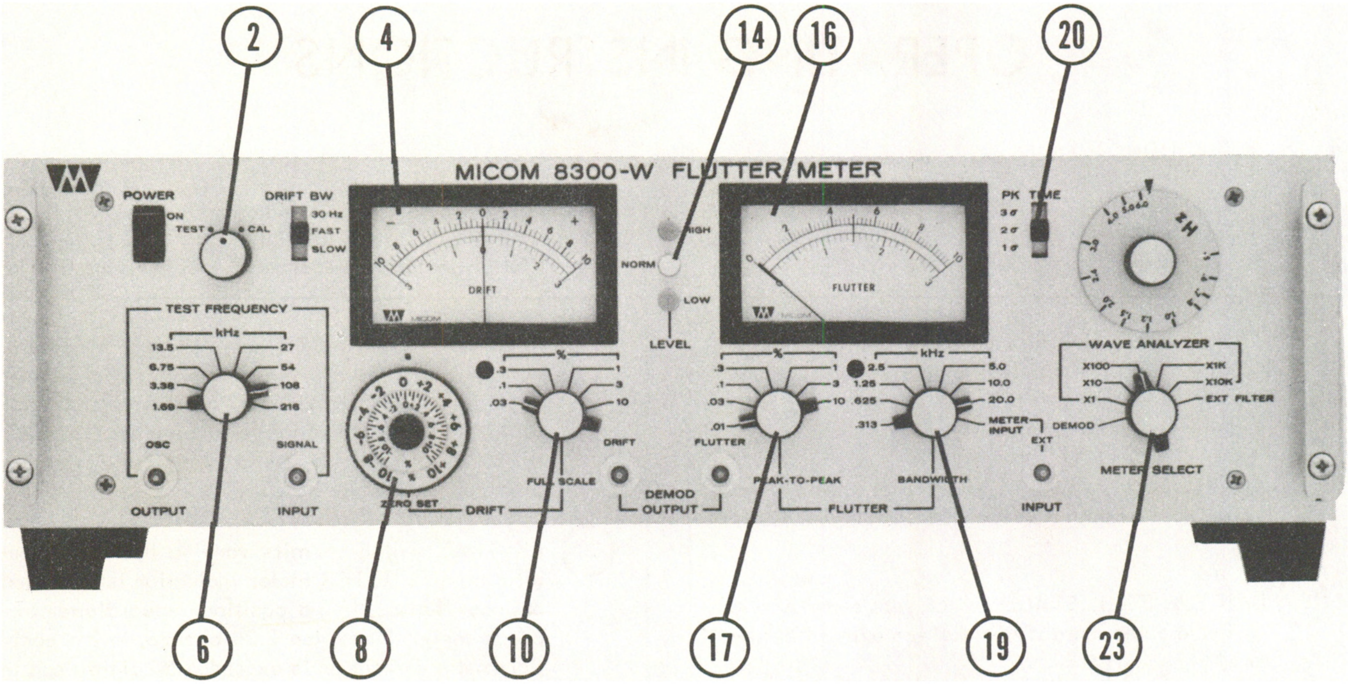
24. AC POWER CONNECTOR provides input connections for ac power.

25. LINE VOLTAGE (115V/230V) switch sets instrument to operate from 115V or 230V ac power line.

26. FUSE provides protection for all line and instrument circuits.

NORMAL CONTROL POSITION SHOWN BY RED ENGRAVING.

INSTRUMENT SELF-CHECK



I. 1. Set TEST FREQUENCY (6) to 216 kHz.

2. Set % FULL SCALE drift (10) to 1%.

3. Set % PEAK-TO-PEAK Flutter (17) to 1%.

4. Set FLUTTER BANDWIDTH (19) to 20 kHz.

5. Set METER SELECT (23) to DEMOD.

6. Set PK TIME (20) to 2 σ.

II. Switch TEST-CAL switch (2) to CAL and hold; NORMAL lamp (14) should light, Zero DRIFT meter (4) with ZERO SET control (8).

III. Switch TEST-CAL switch (2) to TEST and hold 1 minute. DRIFT meter (4) should read +1% .05%. FLUTTER meter (16) should read 1% ± .05% after recovering from switching transient (approximately 15 seconds).

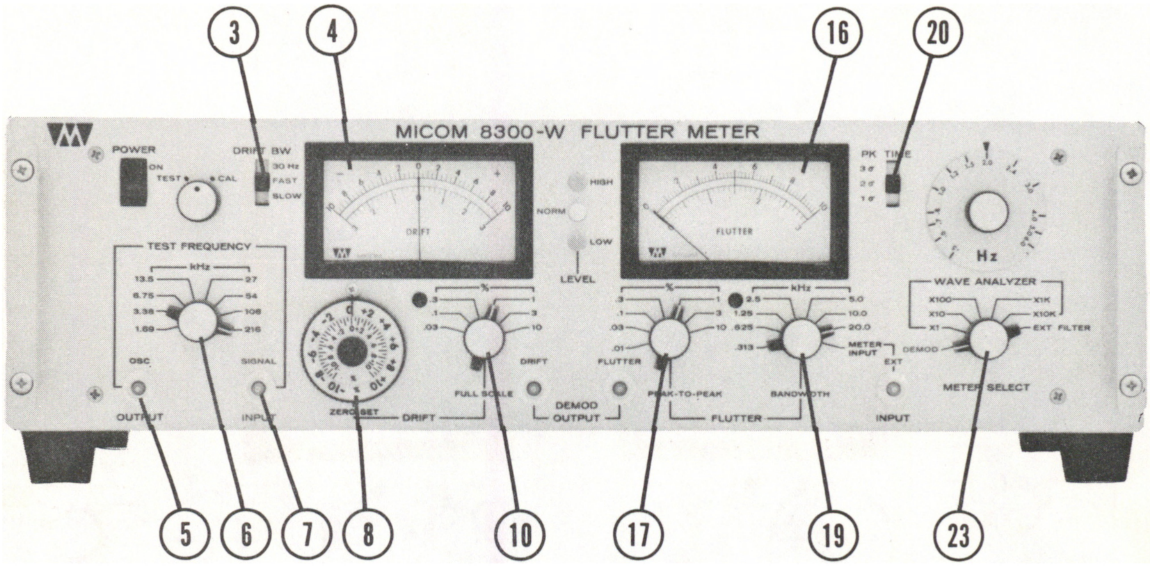
IV. 1. Set FLUTTER BANDWIDTH (19) to 313 Hz, TEST CAL (2) to CAL and hold.

2. Zero DRIFT meter (4) with ZERO SET vernier (8).

3. DRIFT meter (4) should indicate zero 0.1% at 108kHz, 54 kHz, 27 kHz, 13.5 kHz, 6.75 kHz, 3.38 kHz and 1.69 kHz test frequencies. Normal lamp should be lit for each frequency.

FIGURE 3 - 2 INSTRUMENT SELF-CHECK

HOW TO MEASURE FLUTTER



I. Connect TEST OSC OUTPUT 5 to recorder signal input in direct record mode. Choose appropriate test frequency 6 . Use high quality bulk erased tape and adjust level and bias for best signal off tape (see Section 3-4). Make recording of test frequency and rewind tape.

II. Connect recorder output to TEST SIGNAL INPUT 7 . Play back recording and adjust level to approximately 1V rms level.

III. Select FLUTTER BANDWIDTH 19 desired. The FLUTTER BANDWIDTH switch is interlocked with the TEST FREQUENCY switch to permit a maximum FLUTTER BANDWIDTH of 20 kHz at 108 kHz, 10 kHz at 54 kHz, and proportionately less at each TEST FREQUENCY to 313 Hz at 1.69 kHz. See Section I for recommended IRIG bandwidths.

IV. Set DRIFT BW 3 to FAST or SLOW. Center Drift meter 4 with ZERO SET control 8 , with Drift % FULL SCALE switch 10 at desired sensitivity.

V. Place METER SELECT switch 23 on DEMOD.

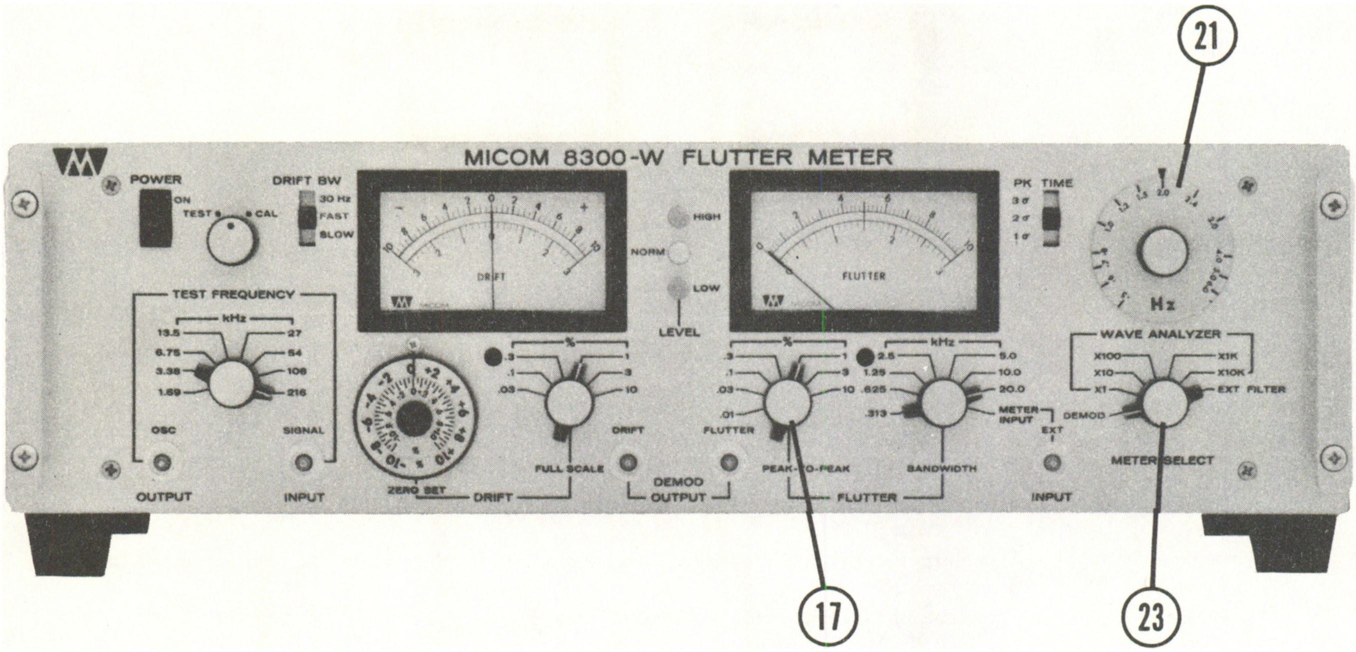
VI. Set PK TIME switch 20 to desired statistical deviation (2 σ – 95% of time, usual; 3 σ true peak-to-peak).

VII. Read peak-to-peak flutter on FLUTTER Indicator 16 .

VIII. Read drift and SLOW variation in speed on DRIFT indicator 4 .

FIGURE 3 - 3 FLUTTER MEASUREMENT

HOW TO ANALYZE FLUTTER



I. Set up system to measure flutter as described on page 3-4.

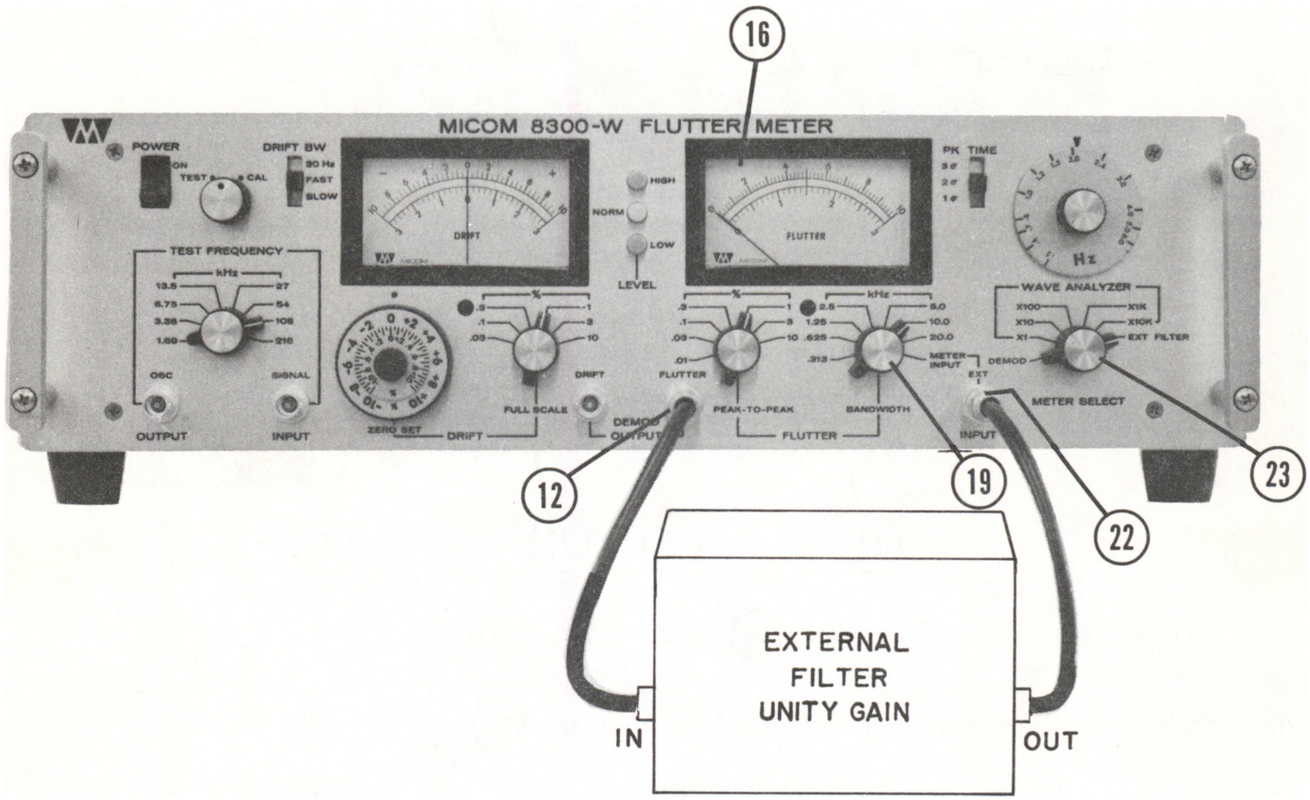
II. Switch METER SELECT switch (23) to desired WAVE ANALYZER frequency range.

III. Slowly tune frequency dial (21) to find frequencies of maximum response of FLUTTER indicator. Increase sensitivity of % PEAK-TO-PEAK switch (17) as required to obtain accurate indications.

IV. Wait for switching transients to die out after changing either % PEAK-TO-PEAK switch or WAVE ANALYZER frequency multiplier with METER SELECT switch (23). On X1 and X10 ranges, start search at 6 on Hz dial (21). Search must be very slow on X1 range to allow analyzer to reach maximum response for each frequency component. (90% of peak response requires $\frac{6.6}{f}$ seconds.)

FIGURE 3 - 4 WAVE ANALYSIS OF FLUTTER

HOW TO USE AN EXTERNAL FILTER



Use of EXTERNAL FILTER in Flutter measurements.

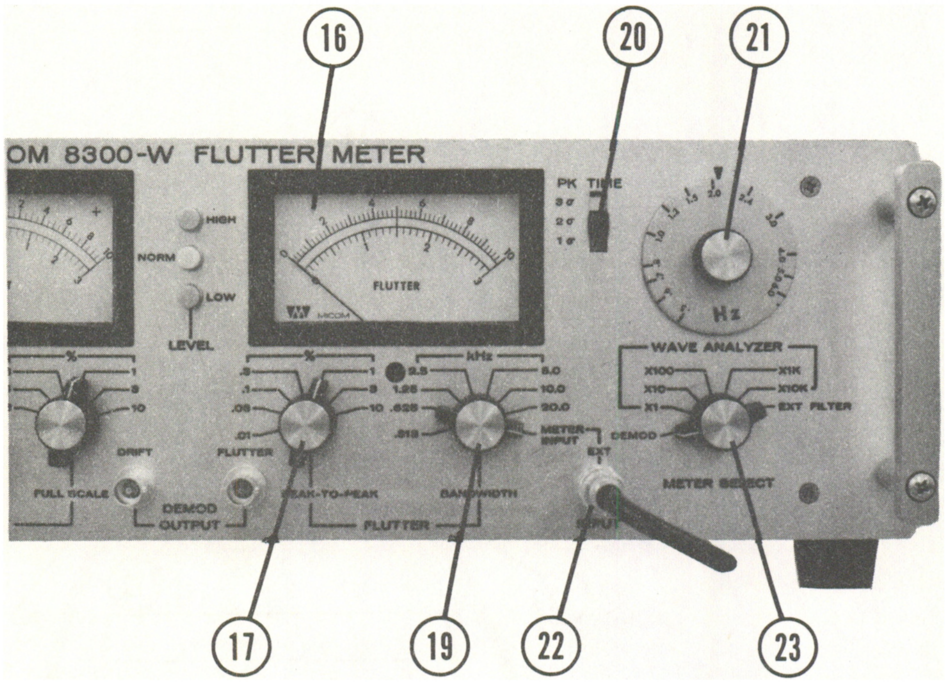
I. Set up system to measure flutter as described on page 3-4.

II. Connect FLUTTER DEMOD OUTPUT 12 to input of unity gain external filter. Connect output of external filter to EXT INPUT BNC connector 22

III. Switch METER SELECT switch 23 to EXT FILTER position. Read Flutter on indicator 16 . Note that bandwidth of flutter measured is that allowed by the internal FLUTTER BANDWIDTH 19 selected in tandem with the bandwidth of the external filter used.

FIGURE 3 - 5 USE OF EXTERNAL FILTER

HOW TO USE 8300-W AS A STATISTICAL VOLTMETER OR WAVE ANALYZER



I. Place FLUTTER BANDWIDTH switch (19) in METER INPUT position.

II. Connect signal to be measured to EXT INPUT BNC connector (22)

III. Switch FLUTTER % PEAK-TO-PEAK switch (17) to range which allows accurate measurement of input on Flutter indicator (16) . Choose desired PK TIME (20)

SWITCH POSITION	FULL SCALE SENSITIVITY peak-to-peak for 3 σ PK TIME
.01%	1 mV
.03%	3 mV
.3%	30 mV
1%	100 mV
3%	300 mV
10%	1 Volt

IV. METER SELECT (23) on DEMOD position measures inputs with a frequency response from below .3 Hz to above 40 kHz at -3 dB, and within ± 0.2 dB from 2 Hz to 20 kHz.

V. When the METER SELECT switch (23) is in one of the WAVE ANALYZER multiplier positions, the FLUTTER indicator (16) indicates the magnitude of the frequency component selected by the Hz dial (21) times the selected decade multiplier.

FIGURE 3 - 6 USE AS VOLTMETER OR ANALYZER

range of .3 Hz to 0.313 kHz, 0.625 kHz, 1.25 kHz, 2.5 kHz, 5 kHz, 10 kHz or 20 kHz is indicated on the FLUTTER meter with a full-scale sensitivity of from .01% to 10%. The DRIFT meter may be centered for any steady speed error of up to plus or minus 10% by means of the ZERO SET control. This control has a vernier resolution of .02%, although the absolute accuracy is only about ± .1% near zero and may be only ± .5% at either extreme of ± 10%.

3-1.2 Input levels from 10 mV to 2V rms may be accommodated. LEVEL indicator lamps automatically indicate when the input is within the range for proper operation. Multi-stage limiters accommodate momentary signal dropouts of up to 40 dB. When the input drops for more than 10 milliseconds below approximately 10 mV, the level required to permit the 40 dB dropouts, the LOW LEVEL lamp glows, the demodulator outputs are clamped to prevent pinning the meters, and the meters return to zero. Excessive levels (above 2V) cause the HIGH signal lamp to glow and also clamps the demodulator output to zero.

3-2 CONTROLS AND INDICATORS

3-2.1 Figure 3-1 illustrates and describes the function of all front and rear panel controls, connectors and indicators. Normal positions are marked in red on the instrument.

3-3 OPERATING INFORMATION

3-3.1 In making a specific flutter or drift measurement, the output of the recorder under test is connected to the signal input connector through a shielded cable. Because low-flutter standard tapes are not generally available for the frequencies and bandwidths of instrumentation recorders used with the Model 8300, it is usually the first step in operating the instrument to make a recording, using the internal test oscillator output as the signal to be recorded.

3-3.2 High quality tape should be used for any such test recording to minimize dropouts which may cause measurement errors. It must be bulk erased before each use. Recording should be done at the speed at which the transport has least flutter. This will usually be the highest tape speed the machine is designed to handle. The frequency to be recorded should be chosen on the basis of the speed of the machine and the flutter bandwidth required during test.

3-3.3 Under normal circumstances the recorder with which the MICOM 8300 is used will provide a standard line output well within the range of voltages for which the 8300 input circuit is designed. Test procedures outlined in the IRIG Descriptive Standard on flutter measurement involving checking sensitivity to instrument noise do not apply when the Model 8300 is in use. The instrument itself provides all the functions described in the IRIG procedure at a level of noise-free and accurate operation guaranteed by the instrument design, rather than by the peculiarities of the particular test set up in use. However, record/reproduce levels must be high enough so that reproduce amplifier noise does not introduce errors. A signal of approximately 1V rms is recommended.

3-3.4 The LEVEL indicator lamps generally indicate whether the recorder signal is adequate for measurement. During rewind, the high-intensity signal sometimes obtained from the recorder output terminals may defeat the signal failure circuit. It is therefore desirable that the reproducer output be turned down or off while rewinding.

3-3.5 The mechanical zero adjust for the DRIFT indicator meter is set to center scale when the instrument is turned off. When the instrument is operating and a reproduced signal is being received the DRIFT ZERO SET dial may be used to compensate for any degree of average frequency error. In many situations where tape transports are operated on line frequencies other than those for which they were designed, or with off-tolerance components such as belts of improper thickness, there may be a net speed error when reproducing the tape, particularly a tape recorded on another instrument or at a different time. However, for most instrumentation use, either 60 Hz servos or sophisticated high-frequency servos are used to stabilize the transport operating speed. The drift indication is then a measure of the degree to which the recorder's internal servo maintains its speed constant and correct. When the DRIFT indicator meter is centered (within 1 or 2%) by the ZERO SET control, the DRIFT and FLUTTER indications are accurately made in percent of the actual input frequency. The DRIFT ZERO SET switch changes the zero frequency by approximately 2% for each major division. The inner-vernier dial covers a range of ±1.1% and has a resolution of better than .02%. Although its absolute accuracy may be only ±0.1%, the CAL procedure allows setting this error to zero.

3-3.6 The % DRIFT switch allows drift of from ± .03% to ± 10% to deflect the drift meter full scale.

3-3.7 In general, when measuring drift directly on the DRIFT indicator meter, the DRIFT BW switch should be set either at FAST or SLOW position. In FAST position the drift-measuring circuit indicates drift variation at rates up to 0.7 Hz and, in SLOW position, up to 0.2 Hz. The bandwidth of the signal delivered for external monitoring to the DRIFT DEMOD OUTPUT connector is 0.7 Hz in the FAST and SLOW positions. The 30 Hz DRIFT BW switch position is intended primarily for use when monitoring the drift at the DRIFT DEMOD OUTPUT. In this switch position, the meter bandwidth remains 0.7 Hz, but the bandwidth of the signal delivered to the DRIFT DEMOT OUTPUT is 30 Hz. With the switch in this position, when measuring drift in the presence of large flutter, flutter signals can overload the meter amplifier and cause the meter indication to be inaccurate. Therefore, in the 30 Hz bandwidth position, if the DRIFT indicator meter is to be used, the signal appearing at the DRIFT DEMOD OUTPUT must be monitored on an oscilloscope or oscillograph. Only when no evidence of clipping is apparent in this signal can the DRIFT indication be trusted.

3-3.8 The % FLUTTER switch permits obtaining indications of flutter of from .01% full scale to 10% full scale. The instrument noise is sufficiently low that accurate measurements are possible on the .01% full scale range. With a

noise-free input signal, the total instrument noise and residual carrier will be less than 10 parts per million rms(0.001%) at the output of the demodulator.

3-3.9 The FLUTTER BANDWIDTH switch permits selecting the bandwidth of the flutter signal measured. Should bandwidths other than 0.313, 0.625, 1.25, 2.50, 5, 10 or 20 kHz be required, an external filter can be used with the instrument. this operation is explained below under the description of the METER SELECT switch. When the FLUTTER BANDWIDTH switch is placed in the METER INPUT position, the flutter measuring circuits become essentially a voltmeter or wave analyzer connected to the EXTERNAL INPUT connector. The FLUTTER indicator meter reads full scale for peak-to-peak voltages one tenth the numerical setting of the % FLUTTER switch (1 mV to 1V).

3-3.10 The METER SELECT switch determines which of three modes of operation of the flutter meter are used. When the switch is set to DEMOD position, the operation of the flutter meter is normal. The FLUTTER BANDWIDTH and % PEAK-TO-PEAK FLUTTER switches operate as labeled.

3-3.11 The WAVE ANALYZER (Model 8300-W only) can be used to measure the individual frequency components of the flutter signal by adjusting the METER SELECT switch to one of the five multiplier positions labeled WAVE ANALYZER. With the METER SELECT switch in one of these positions, the frequency dial indication, when multiplied by the multiplier selected, then indicates the center frequency of the approximately one-tenth-octave band of flutter signal selected for presentation on the FLUTTER indicator meter. The shape of the selectivity curve of the wave analyzer is indicated in Section IV under THEORY OF OPERATION.

3-3.12 The EXT FILTER position of the METER SELECT switch feeds the signal connected to the EXT INPUT connector into the meter system. By connecting an external filter between the FLUTTER DEMOD OUTPUT and the EXT INPUT connector and setting the METER SELECT switch to EXT FILTER the flutter bandwidth of the instrument is determined by the external filter. In this mode, the FLUTTER BANDWIDTH switch operates to limit the overall bandwidth as indicated by the switch setting.

3-3.13 The PK TIME switch provides for setting the integration processes within the flutter meter so as to correspond to: a) true peak-to-peak flutter, b) the IRIG flutter specification or c) approximately average flutter. The labels 1 σ, 2 σ and 3 σ refer to 1, 2 or 3 of the "standard deviations" of statistical analysis. The IRIG Flutter Measuring Method requires that the flutter value which shall be measured is that which is exceeded only 5% of the time. In statistical terms, this corresponds to a peak-to-peak flutter value of 2 standard deviations (2 σ) if the flutter processes are completely Gaussian and random. The 3 σ indication is of that flutter value which is exceeded only 0.3% of the time and essentially corresponds to true peak-to-peak flutter. The 1 σ indication gives the flutter level which is exceeded 32% of the time and corresponds to twice the rms value of truly random flutter. The setting of the switch adjusts a threshold peak reading device so that the threshold is set at a value which is exceeded a given percent of the time by flutter peaks; this threshold value is that displayed by the FLUTTER indicator meter. Note that the statistical flutter indication will track the envelope of the flutter components. In the 1 σ position, increasing flutter inputs are tracked at a rate of 66% of full scale per second. In the 2 σ position, the tracking rate to increasing flutter is 380% of full scale per second. In the 3 σ position, the tracking rate is 5.9% of full scale per millisecond. In all cases the flutter indicator will require 5.5 seconds to recover from full scale indication to zero when the flutter signal decreases at a faster rate.

3-3.14 The DRIFT DEMOD OUTPUT has a frequency range from dc to a frequency determined by the DRIFT BW switch. In the SLOW and FAST positions of this switch, the frequency range is from dc to .7 Hz and in the 30 Hz position, from dc to 30 Hz. The output voltage is ±100 mV for full-scale meter reading, with a source impedance of 1 kilohm unbalanced. The DRIFT DEMOD OUTPUT signal is particularly useful, when recorded by an oscilloscope or oscillograph, for analyzing the transient response of a reproducer during start or stop or when subjected to large transient disturbances of motion.

3-3.15 The FLUTTER DEMOD OUTPUT provides a signal of 100 mV peak-to-peak for full-scale meter indication from a source impedance somewhat less than 100 ohms unbalanced. The FLUTTER DEMOD OUTPUT bandwidth is from .2 Hz to 0.313 kHz, 0.625 kHz, 1.25 kHz, 2.5 kHz, 5 kHz, 10 kHz or 20 kHz, depending on the meter switch setting, at the 3 dB down point. The response starts to fall at 6 dB per octave somewhat below .2 Hz in each case and at >30 dB per octave beyond 1.8X the nominal upper cutoff frequency. Plots of the flutter demodulator bandwidth are given under Section IV, THEORY OF OPERATION.

3-3.16 The TEST OSC OUTPUT voltage is 1 volt with a source impedance of less than 20 ohms unbalanced when driving loads greater than 300 ohms. The test frequencies are 1.6875 kHz, 3.375 kHz, 6.750 kHz, 13.5 kHz, 27 kHz, 54 kHz, 108 kHz and 216 kHz, crystal controlled within ± .005% of the nominal frequency. This output signal is kept very low in both amplitude and phase noise by phase locking it to a crystal oscillator through a series of dividers.

3-3.17 The TEST/CAL switch performs an instrument self check. At 216 kHz Test Frequency and 20 kHz Flutter bandwidth, the TEST/CAL switch is set first to the CAL, or "calibration" position. The DRIFT ZERO SET is then set with coarse steps of the outer switch and fine adjustment of the inner dial until the DRIFT indicator meter is centered. When the TEST/CAL switch is then placed in the TEST position, both the FLUTTER and DRIFT indicator meters should read full scale on the 1% range on 1 σ and 2 σ PK TIME positions. The instrument accuracy checked by this test is set at the factory and can only be corrected under factory conditions.

3-4 OPERATING PRECAUTIONS

3-4.1 Certain recording procedures will, when followed, assure maximum accuracy in flutter measurements:

1. Take care that neither bias, record, nor reproduce amplifiers clip or seriously distort the signals.

2. In general, adjust the recording drive to achieve the maximum possible signal off the tape.

3. Use high-performance, bulk-erased tape to record test signals.

4. It is usually best to record without bias. Particularly, if bias frequency is not very much greater than the test frequency, it is essential to record without bias.

5. Erase signals should not be used unless necessary, and then only if the erase frequency is very much greater than the test frequency.3-4.2 If bias must be used:

3-4.2 If bias must be used:

1. Adjust the bias and signal levels according to the system manufacturer's instructions.

2. With the transport under test connected to the flutter meter, and input to the flutter meter between 200 mV and 1V rms, increase the recording signal approximately 5 dB, then decrease approximately 5 dB. There should be no significant change in the flutter measurement.

3-4.3 If there is a change in the flutter measurement:

1. Reduce the input signal by about 6 dB from Step 1 of 3-4.2 above.

2. Adjust the bias level for peak reproduced output from the transport.

3. Adjust input signal level. If there is a 10 dB (±5 dB) range of input signal level over which the flutter measurement changes less than 10%, set the signal level in the middle of this range.

4. If Step 3 above does not work, reduce the bias, set as in Step 3, so that the reproduced signal from the transport decreases by 3 to 6 dB and repeat Step 2 above.

3-4.4 There must be no cross-coupling between the signal channel under test and other channels carrying signals which can produce beats, cross products or other spurious signals within the pass band of the flutter measurement. It is best to disable all apparatus except the one channel used in making the test.

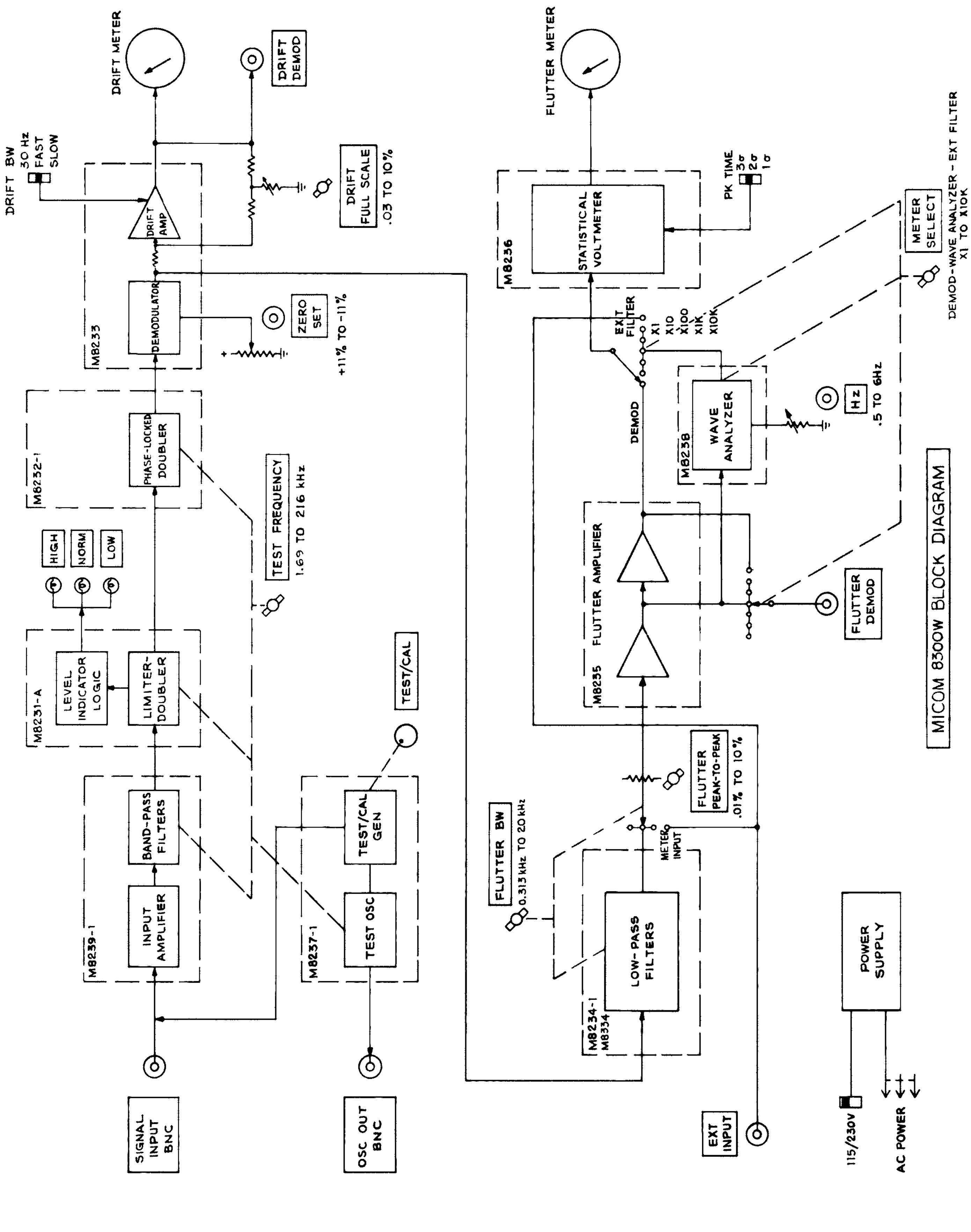


FIGURE 4 - 1 MODEL 8300 BLOCK DIAGRAM

SECTION IV

PRINCIPLES OF OPERATION

GENERAL DESCRIPTION

4-1 ELEMENTS

4-1.1 Models 8300 and 8300-W flutter meters include input bandpass filters, a wide range amplifier-limiter, a high-precision FM demodulator using quantum charge demodulation, a DC drift amplifier, a flutter amplifier with active-filter bandwidth determining filters, a statistical voltmeter for indicating flutter amplitudes, a precision test-oscillator/frequency-divider system, a highly regulated power supply and signal sensing and level indicating circuits. Two meters independently indicate drift and flutter. The block diagram, Figure 4-1, shows the overall scheme of the instrument. The Model 8300-W also includes a .5 Hz to 60 kHz tunable wave analyzer.

4-2 DRIFT MEASUREMENTS

4-2.1 To measure drift, the input signal is coupled to a bandpass filter through an input amplifier stage and the TEST FREQUENCY selector switch. The output signal from the selected filter then goes to the preamplifier-limiter which produces a pulse output at each zero crossing of the input signal. These trigger pulses are applied to the necessary stage of a chain of phase-locked doublers through the Test Frequency switch to produce a trigger rate of 216 kHz at the output of the phase-locked doublers. These pulses are the input to the demodulator. The demodulator converts frequency to current by supplying a precise quantum of charge from a precision capacitor to the output for each input trigger. The integrated sum of such charges results in a current accurately proportional to the frequency of the input signal. This current proportional to frequency is offset by an opposite direct current, derived from a precision current generator, to make the output current zero at the desired center frequency. Zero output at frequencies other than the nominal one selected by the TEST FREQUENCY switch is obtained by varying the voltage to which the precision capacitor is charged each cycle with a high-resolution precision ZERO SET potentiometer. This method of zeroing the instrument causes the output indications to reflect accurately the percent deviations from the actual input frequency and not from the nominal test frequency selected.

4-2.2 The filtered output of the demodulator goes to an operational feedback amplifier, the gain of which is controlled by changing the feedback factor with the % DRIFT switch. The high-frequency cutoff of the amplifier is controlled by capacitive feedback and may be switched from .7 Hz to 30 Hz ± 20% by means of the DRIFT BW switch. The amplifier output drives the DRIFT indicator meter and, after filtering, provides a DRIFT DEMOD signal of ± .1V when the meter reads full scale.

4-3 FLUTTER MEASUREMENTS

4-3.1 A voltage proportional to the output current developed across a precision resistor goes to the FLUTTER BANDWIDTH switch and through the selected flutter bandwidth filter. It then goes through the % FLUTTER switch to the flutter amplifier. The % FLUTTER switch attenuates the input on the 10%, 3% and 1% ranges and sets the gain by feedback control on the .3%, .1%, .01% ranges. The flutter amplifier is followed by a lowpass filter to remove unwanted spurious signals and then to a feedback amplifier with a gain of 12. The signal then passes through the METER SELECT switch. When this switch is in the DEMOD position, the output of the gain-of-12 amplifier is fed to the statistical voltmeter and the input of this amplifier appears at the FLUTTER DEMOD OUTPUT connector. With the switch in the EXT FILTER position, the gain-of-12 amplifier output appears at the FLUTTER DEMOD OUTPUT connector and the signal from the EXT INPUT connector is fed to the statistical voltmeter input. For this switch position alone, the FLUTTER DEMOD OUTPUT level is 1.2V peak-to-peak for a flutter amplitude which will give a full-scale meter indication. For all other switch settings the output level is 100 mV peak-to-peak for a full-scale signal. With the switch in any of the WAVE ANALYZER positions, the gain-of-12 amplifier is not used, since the wave analyzer has an internal gain of 12, and the flutter signal passes through the wave analyzer into the statistical voltmeter.

4-3.2 The statistical voltmeter operates as a floating threshold device, the threshold of which is set by the opposing effect on a precision capacitor of a constant charge drain and an irregular supply of charge provided by flutter peaks. The net voltage on the precision capacitor determines the threshold value. The voltmeter can be so adjusted by the PK TIME switch that the meter indication is that represented by peaks of flutter which are exceeded 32%, 5% or .3% of the time, corresponding to statistical deviations of 1σ, 2σ or 3σ.

4-4 SIGNAL INDICATORS

4-4.1 The signal monitor circuit switches on the LOW signal light whenever the input level drops below about 10 mV for longer than 20 msec. This circuit when switched also removes the offset current from the demodulator and stops the

quantum charge generator from functioning. In this way the meters are brought to zero when the signal is too low for accurate operation. Whenever the signal input exceeds approximately 2V rms, the HIGH signal lamp is turned on, indicating potential overload of the input circuits and corresponding incorrect flutter and drift indications. Whenever either the LOW or HIGH level lamps are turned on, the NORMAL level lamp is turned off.

4-5 TEST OSCILLATOR

4-5.1 The test oscillator is a bridged-T RC oscillator locked to the appropriate stage of a series of binary dividers operating from a master crystal oscillator. An FET amplitude control maintains the locked oscillator output constant. A sample of the test oscillator output, maintained at its nominal level, is fed to the input of the instrument when the TEST/CAL switch is in the CAL position, allowing the ZERO SET control to be adjusted to center the DRIFT indicator meter. In the TEST position, this switch introduces a 100 pps square wave modulation of the demodulator offset current, plus an additional offset of this current of such amplitude that the DRIFT and FLUTTER meters both indicate full scale on the 1% range.

4-6 WAVE ANALYZER (MODEL 8300-W)

4-6.1 The wave analyzer is an active bandpass filter with tuning proportional to the inverse of two RC products multiplied by the amplifier gain factor. The amplifiers are closely stabilized by feedback. Tuning within each band is accomplished by varying "R" with ganged, tapered wire wound potentiometers. Ranges are switched by changing "C" in decade steps with the METER SELECT switch. Selectivity is approximately one tenth octave and the frequency dial calibration is approximately logarithmic.

4-7 REGULATED POWER SUPPLY

4-7.1 The regulated power supply provides +24.0V ±.1V and -24V ±.1V with very good regulation and low impedance and ripple. The +24V supply is the reference for the precision frequency-to-voltage demodulator and is derived from a temperature-compensated Zener reference diode. The -24V regulator uses the +24V supply as the reference for its regulator amplifier.

SCHEMATIC THEORY

4-8 INPUT AMPLIFIER - BANDPASS FILTERS-Card 8239-1

4-8.1 The input test signal is coupled to the selected bandpass filter through a very low noise matching amplifier which presents a high and constant impedance to the signal source, and a low and constant impedance to the bandpass filters. Q1, an FET and Q2, a high-gain, low noise silicon transistor driving Q3, and emitter follower, form a feedback amplifier with a voltage gain of 2 and an output impedance of 2 Kilohms. The output is connected to the limiter amplifier input through the bandpass filter selected by the TEST FREQUENCY switch, S1.

4-8.2 The frequency response of the bandpass filters is shown in Figure 1-3. All filters except the 216 kHz filter have a bandwidth of approximately ±30% of center frequency which is wide enough to include all first-order side-bands from modulating signals up to the maximum flutter bandwidth allowed at each carrier frequency. This is 20 kHz with a 108 kHz center frequency and proportionally less with decreasing center frequency. At 1.69 kHz center frequency, the maximum allowed modulating rate is 313 Hz. The 216 kHz bandpass filter bandwidth is approximately ±13.5% of center frequency, and accommodates all first-order side-bands at modulating rates up to 20 kHz. The steep rates of attenuation outside the band edges contribute to the ability of the instrument to make accurate measurements with noisy inputs. Although the non-constant phase filters do not provide optimum measurement linearity and can convert some AM noise to FM, their superiority to constant-phase filters in rejecting out-of-band noise outweighs their disadvantages. Distortion and noise in the FLUTTER DEMOD OUTPUT is less than 0.2% with 10% peak-to-peak modulation at 108 kHz at a 1 kHz modulation rate, and less than 0.5% at a 20 kHz modulation rate. The distortion in the DRIFT DEMOD OUTPUT is negligible.

4-9 LIMITER AMPLIFIER AND DOUBLER - CARD 8231A

4-9.1 The signal limiter amplifier is a comparatively low noise amplifier with a very large dynamic range. Input level sensing circuits allow the instrument to indicate only when the input is within the operating range and control lamps to inform the operator of the input level.

4-9.2 Q1 provides gain with shunt limiting through CR1 and CR2, a matched pair, when its output exceeds the approximately ±.6V threshold of the diodes. Q2 provides further gain with limiting through CR3 and CR4. Q3 and Q4 operate similarly with limiting provided through CR5 and CR6, and CR7 and CR8, respectively.

4-9.3 Isolation from noise voltages within the instrument is provided by R7, C3, R9, C8 in the first stage, R14, C10 and R16, C12 in the second stage, and by R19, C14 in the third stage.

4-9.4 The output of the fourth limiting stage is coupled to a symmetrical differential amplifier Q5 and Q6, which provides two complimentary outputs which are differentiated by C16, R23, and C17, R26 and mixed through Q8 and Q9 to provide output pulses coincident with each zero crossing. When the TEST FREQUENCY switch is in the 216 kHz position Q9 is inhibited, thereby causing a 216 kHz trigger output for 216 kHz inputs.

4-10 SIGNAL LEVEL DETECTION CIRCUITS - CARD 8231A
4-10.1 The output of the first limiter stage is coupled through R30 to Q10, a common emitter amplifier. The voltage

gain of Q10 is set by R37 (in conjunction with its collector load) to cause Q11, acting as a peak rectifier, to cut off Q12 when the input voltage is above 6 to 10 mV rms. When the input is below this threshold, Q12 is turned on by current through R39, and in turn switches on Q13 which drives the LOW level lamp. When Q13 is turned on, Q14 which controls the NORMAL signal lamp, is turned off through CR9. C22 allows the input to remain below the low threshold for approximately 10 msec without activating the signal lamp.

4-10.2 The input signal at pin 3 is monitored by Q16 which acts as a peak detector to turn on Q17 when the input signal exceeds 2 to 2.5V rms. When Q17 is on, Q18 is turned off, allowing current through R56 to turn on Q15 which drives the HIGH level lamp. C23 filters the pulses from Q16 and provides some delay so that the circuit is not activated by occasional spikes of input noise. When the HIGH lamp is turned on by Q15 the NORMAL lamp drive, Q14, is turned off through CR10.

4-10.3 Whenever CR9 or CR10 are brought to about -22V by the HIGH or LOW lamp drivers the operating current of the differential doubler stage is removed through R21, cutting off Q7. This stops the output triggers, and hence stops the Quantum Charge Generator. The voltage at the junction of R21 and R25 is brought to approximately +5V causing CR8 on board 8233 to conduct, thereby removing the constant offset current from the output of the demodulator. These actions provide zero output from the demodulator whenever the input signal is too high or too low for proper operation.

4-11 PHASE-LOCKED DOUBLER CHAIN - CARD 8232-1

4-11.1 The limiter amplifier provides a pulse output coincident with each zero crossing of the test frequency. The Demodulator operates at a nominal 216 kHz. When the test frequency is 216 kHz, only one zero crossing pulse per cycle is used; with 108 kHz test frequencies, both zero crossing pulses per cycle are used. Test frequencies below 108 kHz are coupled to the selected stage of phase-locked doublers through the TEST FREQUENCY switch S1, to provide an output frequency of 216 kHz.

4-11.2 The operation of the phase-locked doublers may be understood by referring to the schematic of one stage in Figure 4-2.

Input triggers are differentiated by C2 and R4, and cause Q2 to saturate, clamping point A to zero volts momentarily. The charge collected by C4 during the previous period is transferred to C5 through CR3, causing B to go positive, thereby turning off Q5. i_2 causes the voltage at B to run down at a

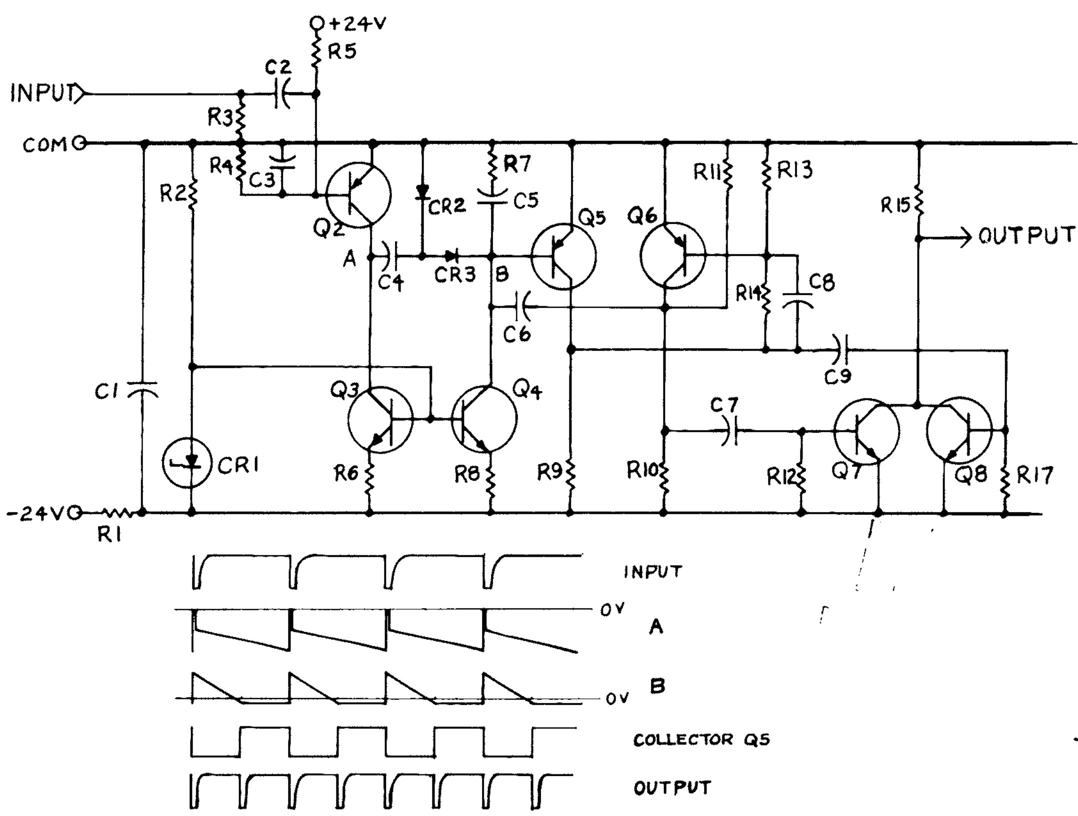


FIGURE 4 - 2 PHASE LOCKED DOUBLER

linear rate until Q5 again conducts, at which time the voltage at B is clamped at -.6V by the base of Q5. If $i_2 = 2i_1$, the time Q5 is turned off will be exactly one half the period between input triggers. Consideration of conservation of charge shows that the exact values of C4, C5, the diode drops across CR2, CR3, or the saturated voltages of Q2 or Q5 will not affect symmetry of the doubling process as long as none of those values change during the cycle. C6 and C8 speed up the transitions of Q5 and Q6, and double frequency output pulses are provided by differentiating the transitions of Q5 and Q6 by means of C7-R12 and C9-R17 to drive Q7 and Q8. Adequate symmetry for proper operation is maintained over a 2:1 frequency range - well beyond the ±10% full scale range of the Model 8300 Flutter Meter.

4-11.3 The doubled frequency output pulses from the limiter amplifier are coupled to the selected stage of phase-locked doublers through the TEST FREQUENCY switch, S1. The phase-locked doubler chain is used at 54 kHz and lower carrier frequencies. When 54 kHz test signals are used, the 108 kHz double frequency pulses from the limiter are connected to the base of Q37 to obtain one stage of phase-locked doubling. For a 27 kHz test signal, the doubler output pulses are connected to the base of Q30 to provide two stages of phase-locked doubling. Another stage of phase-locked doubling is added at each lower test frequency until at 1.69 kHz, six stages of doubling are used.

4-11.4 The 216 kHz pulses from the limiter when 108 kHz signals are used are connected directly to the output, as are the 216 kHz pulses derived from a 216 kHz test frequency.

4-11.5 CR1, a 6.5V breakdown diode, supplies a fixed voltage bias to the bases of all the constant current generators, Q3 and Q4, Q10 and Q11, Q17 and Q18, Q24 and Q25, Q31 and Q32, and Q38 and Q39. R43 and C27 isolate the circuit from the rest of the apparatus. A resistor connected to the +24V supply, and a small capacitor at the input circuit of each doubler protect the doublers from false triggering caused by transients within the instrument. In Figure 4-2, these components are C3 and R5.

4-12 QUANTUM CHARGE GENERATOR - DEMODULATOR - CARD 8233

4-12.1 The 216 kHz output pulses of the phase-locked doubler chain or the differential squaring amplifier causes a one-shot, Q1 and Q2, to fire once for each input trigger. The period of the one-shot is approximately 1.5 μ sec. When the one-shot fires, Q1 is turned on applying $\sim$0V to the base of Q4, which then conducts and turns off Q6 and turns on Q5, which saturates. When Q5 saturates, its collector voltage is brought to within a few millivolts of the +24.00 volt reference, thereby charging the Quantum Charge Generator (QCG) precision capacitors, C7, C8 and C9, through R34, a precision resistor. The voltage to which the precision capcitors are charged is controlled by the current through R30 and the voltage output from the ZERO SET potentiometer controlling the output of Q3. The time constant of R34 and the QCG capacitors is less than one sixth of the period, so the final voltage at the end of the one-shot period is precisely controlled. When the one-shot recovers, the output of Q1 becomes approximately -6V, and Q4 and Q5 are turned off. Q6 then applies a constant negative current to the precision QCG capacitors until they are clamped to a voltage of approximately -1.2V by CR6 and CR7. During the one-shot period, the QCG capacitors are charged through CR9, and when Q6 is turned on, the charge is delivered to the emitter of Q8. The β of Q8 exceeds 300, therefore < 99.7% of the quantum of charge is delivered to the output through Q8. At the output, the quantum of charge delivered at each cycle of the one-shot is added to a constant 1mA supplied by Q7, a precision, temperature-compensated, constant-current supply.

4-12.2 The temperature effects of Q8 and CR9 are compensated by very similar effects in CR6 and CR7. The precision of the demodulator is primarily established by the stable reference voltage, stable silver mica capacitors and stable metal film resistors. Second order thermal effects are predictable and compensated by the same effects in similar components. The quantum of charge delivered each cycle is directly proportional to the voltage to which the precision capacitor is brough each cycle. This voltage is controlled over a ±11% range by the ZERO SET potentiometer which is of the Kelvin-Varley type. 2% increments are provided by switching across precision metal film dividers and ± 1% vernier is provided by an interpolating potentiometer R12. The correction voltage is shaped to approximately the necessary segment of a reciprocal curve to increase the accuracy of the calibration of the ZERO SET control.

4-12.3 The precise value of the QCG capacitor is adjusted to provide zero output from the discriminator when the input is 216.00 kHz and the ZERO SET is in the 0.0% offset position.

4-12.4 L1, C4 and R19, C2 decouple the pulses generated within the demodulator from the rest of the instrument.

4-13 DRIFT AMPLIFIER SECTION - CARD 8233

4-13.1 The Drift Amplifier is an operational DC amplifier with a balanced silicon input transistor pair, Q9 and Q10. Q9 and Q10 are selected for balance and mounted with close thermal coupling to maintain excellent balance over the normal temperature range. Gain is determined by feedback through R73 and R74 in conjunction with the input resistor, R52. The % DRIFT switch, S4, attenuates the feedback to set the gain on all but the 10% range. Bandwidth is determined by capacitive feedback; when the DRIFT BW switch is in the 30 Hz position maximum bandwidth results. In the DRIFT BW FAST position C15, C16, C21 and C22 restrict the amplifier and meter bandwidth to 0.7 Hz. In the SLOW position the amplifier bandwidth remains 0.7 Hz but the meter response is restricted to approximately 0.2 Hz by C17 and C18. To insure low interaction in the presence of flutter signals many times larger than full scale input for the drift amplifier, a clamp circuit consisting of Q15 and Q16 clamps the output by feedback whenever overload occurs. At full scale the output of the amplifier is 6V. R75, C23 and R76, C24 form a low pass filter to minimize carrier components in the DRIFT DEMOD output, taken from the junction of R76 and

R77. C24 is mounted on the DRIFT DEMOD output BNC connector on the front panel.

4-14 LOW PASS FILTER - CARDS 8234-1 & 8334

4-14.1 The 8234-1 card contains three active low-pass filters of identical design for 5 kHz, 10 kHz and 20 kHz bandwidth. The 8334 card contains four active low-pass filters of the same design for 2.5 kHz, 1.25 kHz, 0.625 kHz, and 0.313 kHz bandwidth. The transmission characteristics of the filters are as shown in Figure 1-4.

4-14.2 Q1 and Q2 and C1, C2, C3 and C4 establish the operating voltages for the active circuits and provide decoupling from all sources of noise and interference in the rest of the instrument. Each complete filter consists of two stages of 3-pole filter elements having a very low output impedance. Figure 4-3, an abstract of the complete schematic shows the configuration of the filters themselves.

4-14.3 The pass band performance is controlled by Ra, R7, R8 and C5, C6, C7 in the first section and R14, R15, R17 and C8, C10, C12 in the second section. (Ra is actually located on 8233 as R52, where it forms the input resistor for the Drift Amplifier input pair Q9 and Q10. The filters are designed to provide a voltage gain (K1 K2) of 4.32 and to operate at Zero to +350 mV DC output when the input is zero.

4-14.4 The 8334 card contains the 2.5 kHz, 1.25 kHz, 0.625 kHz, and 0.313 kHz low pass filters. Filtered supply voltage for these filters is obtained from the 8234-1 card.

4-14.5 The FLUTTER BANDWIDTH switch connects the demodulator output to the input of the selected filter and the output of that filter to the % FLUTTER sensitivity switch. The output of the filter is 1 mV peak-to-peak for .01% peak-to-peak flutter and a maximum of 1V peak-to-peak for 10% flutter.

4-15 FLUTTER AMPLIFIER - CARD 8235

4-15.1 The flutter amplifier is a very low noise feedback amplifier which has its gain determined by feedback. Q1 and Q2 are selected FETs and Q3 is a common-emitter stage with its operating point set by CR1, a constant voltage diode. Potentiometric feedback to the gate of Q2 through R15 determines the gain. On the most sensitive range the gain is 100, set by R1; the gain is reduced to 33.3, 10 and 3.33 by feedback attenuator resistors R2, R3 and R4 respectively, on the % PEAK-TO-PEAK FLUTTER switch. Lower sensitivity is provided by attenuating the input with R5, R6, R7 and R8 on the same switch.

4-15.2 The output of the amplifier, at a 100mV peak-to-peak level for full-scale output, passes through an active lowpass filter with unity gain, Q5 and Q6. The amplifier and filter provide a flat output from .2 Hz at -3dB to beyond 20 kHz. The frequency response is flat, ±0.2dB, from 2 Hz to 20 kHz, and is down more than 12dB at 54 kHz, falling at 18dB/octave above about 80 kHz.

4-15.3 The output of the lowpass filter is connected to the FLUTTER DEMOD output connector and to Q7 and Q8, a feedback pair with a gain of 12, to provide a 1.2V peak-to-peak full scale input to the statistical voltmeter. CR2 provides a temperature-compensated bias for the second stage to obtain a small constant DC offset at the output.

4-15.4 R9, C2 and R14, C3 decouple the flutter amplifier from the power supply, and CR3 provides a low impedance bias for Q8.

4-16 STATISTICAL PEAK READING VOLTMETER - CARD 8236

4-16.1 The statistical peak reading voltmeter consists of two sections; one operates on positive excursions of the input; an identical section with reversed polarity components operates on negative excursions. To explain circuit operation, consider first the block diagram in Figure 4-4. Whenever the input signal is more negative than some particular value determined by the dc feedback, the negative peak comparator turns on the Gated Current source. This is a fixed current while it is turned on and feeds current to the input of the integrator. When the gated Current Source is off, input current flows out of the integrator because of the fixed current I_F. The integrator smooths these current pulses and produces a dc feedback signal which adjusts itself so that the Gated Current

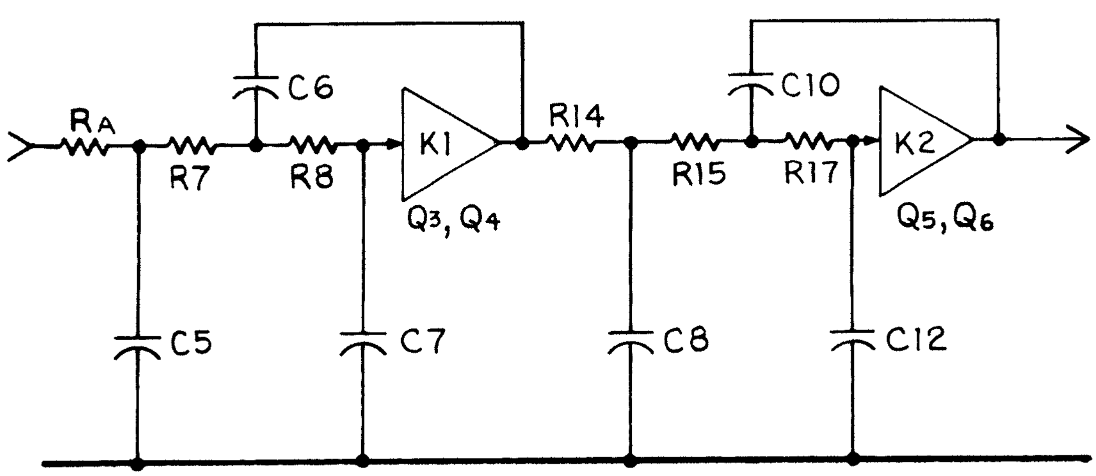


FIGURE 4 - 3 LOW PASS FILTER

source is turned on for just enough time to cause the average input current to the integrator to be zero. Zero integrator input is required for a fixed integrator output. The fraction of time the Gated Current source is turned on, and hence the fraction of time the input is above the negative threshold determined by the dc feedback is fixed by the ratio of the Gated Current Source to the Fixed Current Source, and this establishes the basic statistical reading feature of the instrument. The positive peak comparator works in the same way, except with all polarities reversed. A dc voltmeter placed between the dc feedback lines reads the peak-to-peak level, the input signal will be found within for the fraction of time determined by the ratio of Gated to Fixed Current Sources. Q1 and Q2, a differential pair, compare the negative input excursions through C1 to a threshold held at the output of Q11 by C6. When the input is more negative than the threshold, Q1 is turned off, thereby turning off Q3, a common-emitter amplifier. The output of Q3 is the input of Q4 and Q5, a Schmidt trigger. Q1 through Q5 make up the negative peak comparator. When Q3 is off, Q5 forward biases Q6 approximately 10V, causing a positive current of approximately 100 μA, 550 μA, or 10 mA depending on whether S8, the PK TIME switch, is in the 1σ, 2σ or 3σ position, to charge C6. Q5 is the Gated Current Source on the negative side. A constant current of approximately -13.5 μA through R20 discharges C6. R20, a large resistor returned to a relative high voltage is the fixed current source. The voltage across C6 is the input to a very high gain operational amplifier, Q7, Q8, Q9, Q10 and Q11. Since the input voltage and current of Q7 has a negligible change for any output, the circuit will reach equilibrium only when the average current supplied by Q6 equals the current discharged through R20. To do this, the output, (and input threshold) is forced to that value required so that the input excursions exceed the negative threshold 15%, 2.5% or 0.15% of the time for 1σ, 2σ or 3σ reading respectively. The positive input threshold is established by identical action of the corresponding elements of the other half of the voltmeter. A 200 μA meter, M2, with proper resistance for optimum damping is connected between the positive threshold output and the negative threshold output. The meter thus reads the peak-to-peak input voltage to 1σ, 2σ or 3σ limits. CR1, CR2, CR3 and CR4 clip input excurisons at approximately 2 times full scale to help speed up recovery of the instrument from large transients caused by turn-on, range switching, etc. R1, C3 and R2, C2 isolate the rest of the instrument from the heavy pulses and switching waveforms occurring within the peak reading voltmeter.

4-17 TEST OSCILLATOR - CARD 8237-1

4-17.1 The test oscillator assembly is made up of several sections: a crystal oscillator, a chain of binary dividers, a locked RC oscillator and a test square-wave modulator.

4-17.2 The crystal oscillator is a conventional emitter-coupled pair Q1 and Q2, operating at the series fundamental mode of Y1, Q3 couples the output to a low pass filter for synchronizing the locked oscillator. and drives Q4 to switch the first stage of a chain of dual J-K integrated-circuit flip-flops, FF1 through FF4, which divide the input to provide the desired test frequency. The output of each divider is filtered to provide a synchronizing signal to the locked oscillator.

4-17.3 The locked oscillator is a bridged - T RC oscillator with an FET amplitude regulator. The synchronizing signal is injected into the frequency-determining network with sufficient amplitude to cause locking in spite of large variations in component values. When such a synchronizing signal is injected, the amplitude regulation circuit causes the RC oscillator to become a highly selective amplifier with constant output level. Q5, Q6 and Q7 form the RC oscillator, Q9 and Q10 regulate the output level. Q11 and Q12 form a feedback pair to provide a 1V rms ±10% output test signal with a very low dynamic impedance.

4-17.4 Q14 and Q15 form a pulse generator with a rate of approximately 200 pps that is allowed to run when the test

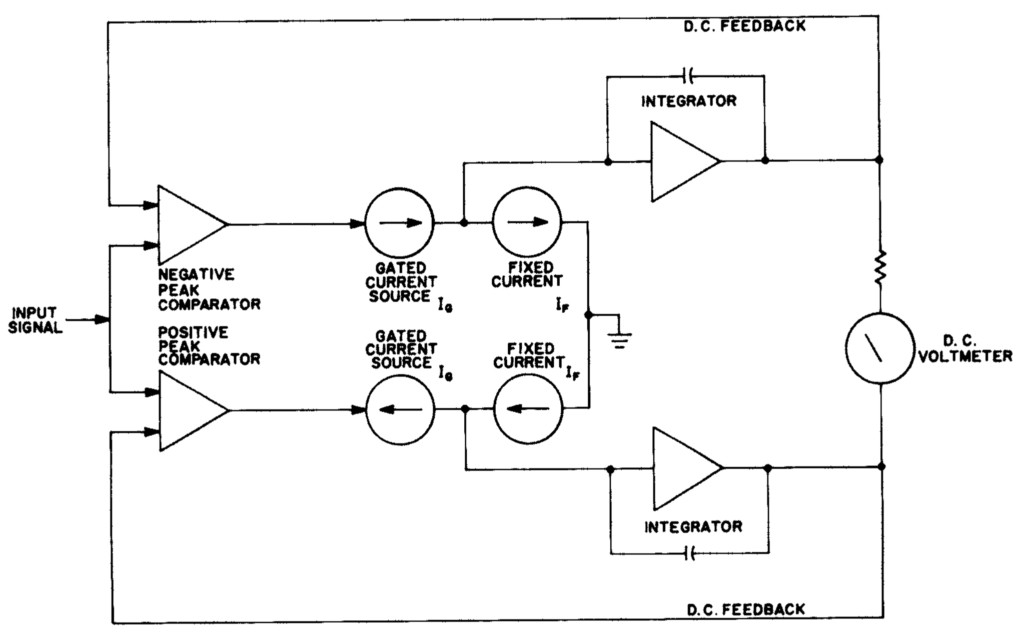


FIGURE 4-4 STATISTICAL VOLTMETER BLOCK DIAGRAM

switch is in the TEST position. One section of FF1 is switched by the test generator, providing a 100 pps square wave switching signal with excellent symmetry. The switching signal turns on and off Q16 which modulates the offset current of the demodulator 1% peak-to-peak. The TEST switch also turns on Q17 to add another 1/2% DC modulation of the offset current. Another pole of the TEST switch couples the test frequency into the instrument so that the demodulator output is shifted +1% DC with a 1% peak-to-peak square wave modulation.

4-18 REGULATED POWER SUPPLY - 8230

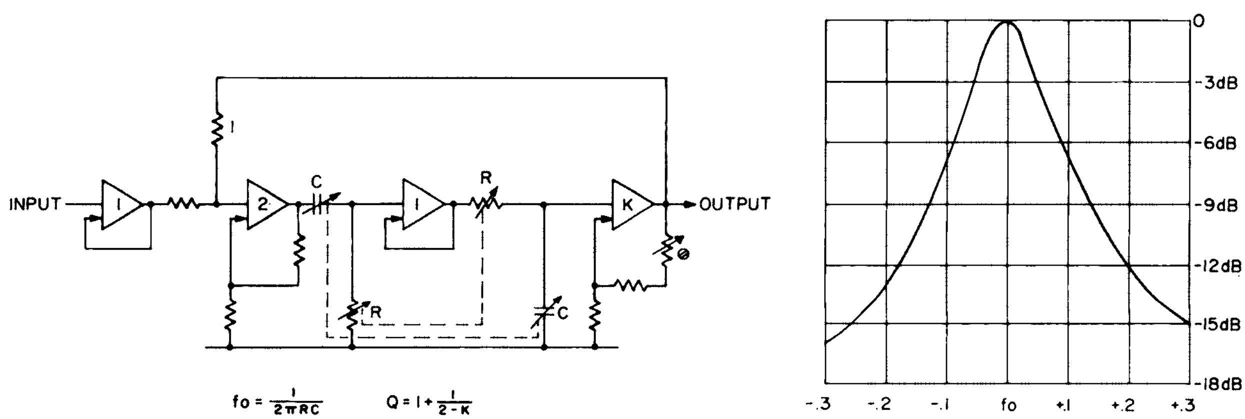
4-18.1 The regulated power supply is constructed as a self contained module. The input transformer is designed for 48 - 64 Hz operation at 115 or 230V ± 10%. S10 must be switched to the appropriate position for the line voltage used. The supply is designed to provide + and - 24V at up to 500 mA. Noise and 120 Hz ripple is less than 200 μV and variations in output will be less than 1/2% over the 60°C ambient range of operation or the ± 10% range of line level.

4-18.2 Operation of the regulator will be understood by reference to the schematic 8230. The output voltages of the shielded power transformer are full-wave rectified by CR1 and CR2 to provide + filtered DC across C5 and rectified by CR3 and CR4 to provide - filtered DC across C6. C1, C2, C3 and C4 suppress high frequency transients from the power line. The positive output voltage is set by Q1, a germanium power transistor, under the control of Q8, a voltage amplifier. Q8 amplifies the output of Q4, an error amplifier, which amplifies the difference between the breakdown voltage of CR7 and the fraction of the output voltage developed across R11 by R9 and R10 in series. The breakdown voltage of CR7 was chosen to compensate the -2 mV/°C variation in base-to-emitter voltage of Q5. R9 is adjusted to provide 24.00 ±.02V output. C8 and R7 contribute to the high frequency stability, C14 reduces the 120 Hz supply ripple, and C11 provides a low dynamic impedance output at high frequencies. The negative regulator uses the +24V output as its reference. The voltage from the precision divider R24 and R28, connected across the +24V and -24V outputs is compared with a fraction of the -24V from the divider, R6 in parallel with R13, and R12 by a differential pair, Q6 and Q7; the error voltage is amplified by Q5 and applied to Q2, a germanium power transistor, in the sense which reduces the error. R6 is selected to make the output voltage -24.00 V ±100 mV. Q3 is used as a constant-current load for the collector of Q5 to maintain a very high voltage gain for the error amplifier. C9 and R14 contribute to the high-frequency stability of the circuit and C10 provides a low output impedance at high frequencies.

4-19 WAVE ANALYZER - CARD 8238

4-19.1 Figure 4-5 is a black diagram of the Wave Analyzer. The input signal through C1 is attenuated by divider R1-R4 to provide an overall gain of 12 at the frequency of maximum response. Q1 and Q2 provide a stable gain of 2 to make up the loss in mixing the input and output through R10 and R11 as the input to feedback pair Q3 and Q4. The low-impedance output of Q4 drives the first phase-shift network, C2 through C6 and R2A in series with R22. The voltage at the junction of C2 through C6 and R22 is amplified by Q5 and Q6 at approximate unit gain and applied to the second phase shift network, R1B in series with R27 and C7 through C11. The output at R27 is applied to feedback amplifier Q7 and Q8, the output of which goes to the statistical peak reading voltmeter through S9C when in the WAVE ANALYZER positions of S9. R38, a wire-wound screwdriver adjustable resistor, adjusts the analyzer to provide a 3dB bandwidth of 5% of the frequency of maximum response. The response will be down more than 20 dB at 1/2 and 2 times the frequency of maximum response. R2A and R2B are ganged wire-wound potentiometers, tapered to provide an approximately logarithmic frequency scale. C2 and C7 are matched for .5 to 6 Hz operation, C3 and C8 matched for 5 to 60 Hz, C4 and C9 for 50 to 600 Hz, C5 and C10 for 500 Hz to 6 kHz, and C6 and C11 for 5 kHz to 60 kHz operation. R22 and R27 have selected shunt resistors to calibrate the high frequency end of the tuning range. R40, C12 and R3, C13 isolate the analyzer from other circuits in the instrument.

WAVE ANALYZER



$f_o = \frac{1}{2\pi RC}$ $Q = 1 + \frac{1}{2-K}$

R VARIABLE OVER 12:1 RANGE
C SWITCHED IN DECADE STEPS

FIGURE 4 - 5 WAVE ANALYZER

SECTION V

MAINTENANCE AND CALIBRATION PROCEDURES

5-1 INTRODUCTION

5-1.1 This section provides maintenance and service information for the Model 8300/8300-W Flutter Meters. These are precision instruments designed to provide long, trouble-free service without requiring maintenance or adjustments. To check the calibration of the instrument to full accuracy will require instruments not normally available except in the largest laboratories. If trouble is experienced with an instrument, it is recommended that the instrument be returned to:

MICOM, Inc.
855 Commercial Street
Palo Alto, California 94303
Telephone (415) 328-2961

for prompt repair or recalibration.

5-2 TEST EQUIPMENT

5-2.1 Recommended test equipment for performance checking and troubleshooting is listed in Table 5-1. Other instruments may be used if their specifications or performance equals or exceeds the required characteristics.

5-3 INSTRUMENT COVER REMOVAL

5-3.1 Unscrew and remove the six countersunk phillips-head screws holding each cover on. Covers may then be lifted off. When replacing covers make sure the top cover which has a cork strip inside is put back on the top.

5-4 TROUBLESHOOTING AND REPAIR

5-4.1 SELF CHECK: When malfunction is suspected, disconnect all equipment from the instrument and perform the self check procedure given in Figure 3-2. If the instrument self checks properly, check that the input is within the frequency and amplitude limits of specifications. For example, the test input signal may be intermittent, contain a large interfering component, or have a poor signal-to-noise ratio. Damaged connecting cables may be causing intermittent connections or noise. If malfunction still persists make performance checks to help determine the location of the trouble.

5-4.2 SUBSTITUTION: Troubleshooting is greatly simplified if checking is done by replacing a suspected plug-in circuit card with one known to be operating properly. When a malfunctioning card is found, trouble may be traced to the offending component, or the card returned to MICOM for repair.

5-4.3 TROUBLESHOOTING OF CIRCUIT CARDS: Refer to Section IV, Principles of Operation, for details on the operation of all assemblies used in the Model 8300/8300-W. Reference to the schematic for each circuit card will show key waveforms and operating DC levels to help isolate faulty components. For easy access to operating plug-in cards, use the PC board extender included with the instrument, attached to the card cage behind the switch plate.

5-4.4 PRINTED CIRCUIT COMPONENT REPLACEMENT: To prevent damage to the circuit board, apply heat sparingly

Instrument Type	Required Characteristics	Recommended Instrument
Wideband Function Generator	0.1 Hz to 100 kHz Sine wave, triangular waves	Wavetek Model 110
Wideband Sine Wave Oscillator	10 Hz to 1 M Hz	HP Model 651A
AC VTVM	10 mV to 300 V full scale 1% accuracy to 100 kHz	HP Model 400H
DC Voltmeter	100 mV to 100 V F.S 0.2% Accuracy	HP Model 3430A
Precision Frequency Modulator	1.6875 to 216 kHz center freq. 10% modulation range with 0.1% linearity & 20 kHz bandwidth	Micom Model 9100 FM Test Set
Oscilloscope	10 mV/div to 10V/div DC to 15 mHz	Tektronix Model 422
Distortion Analyzer	1 kHz to 300 kHz	HP Model 333A

TABLE 5 - 1 RECOMMENDED TEST EQUIPMENT

and work carefully. A 37-1/2 Watt iron with a small, clean tip is recommended. Replacement procedure:

a. Remove defective component.

b. Melt solder in component lead holes and remove excess solder with clean dry iron. Clear holes with a thin toothpick or a suction type solder removal tool, pushing from trace side of card.

c. Bend leads of replacement component to fit and insert component leads in holds. Solder leads in place, using heat and solder sparingly.

d. If a pad or printed circuit trace is lifted, press conductor pad against the board and hold until solder cools so that the component lead holds pad firmly in place.

5-5 PERFORMANCE CHECKS AND CALIBRATION

5-5.1 POWER SUPPLY:

a. Set line voltage to normal value: 115V or 230V ac.

b. +24.0 volt supply rail (pin 15 on any PC socket) should read 24.0 ±0.1 V dc. If outside this range adjust R9 (15T screwdriver pot) on power supply module.

c. -24V supply rail (pin 1 on any PC socket) should read -24.0 ±.2V dc. If outside this range, adjust R6 on power supply module.

d. Vary line voltage from 105 to 130V ac or from 210 to 260V ac. The +24 dc rail should not vary more than ±.05V dc.

5-5.2 TEST OSCILLATOR:

a. Connect OSC OUTPUT to frequency counter and measure each test frequency. 216 kHz frequency should be 216,000 Hz ±20 Hz; 108 kHz frequency should be 108,00 Hz ±10 Hz; 54 kHz frequency should be 54,000 Hz ±5 Hz; 27 kHz frequency should be 27,000 Hz ±3 Hz; 13.5 kHz frequency should be 13,500 Hz ±2 Hz; 6.75 kHz frequency should be 6750 Hz ±1 Hz; 3.38 kHz frequency should be 3375 Hz ±1 Hz, and 1.69 kHz frequency should be 1687.5 Hz ±1 Hz. If outside these limits, the crystal oscillator has failed or the output oscillator has failed to lock. Refer to Section IV, Theory of Operation, and the schematic 8237-1 for help in locating the fault.

b. Connect OSC OUTPUT to a distortion analyzer. Output voltage should be 1 V rms ±10% and distortion less than 3% at all test frequencies.

5-5.3 SIGNAL INPUT THRESHOLDS

a. Connect wideband sine wave oscillator (HP651A or equivalent) to TEST INPUT with AC Voltmeter (HP 400H or equivalent) monitoring input and measure threshold at which low lamp turns off at each test frequency. This level should be between 6 mV and 10 mV. If outside this range, check the signal through the input amplifier, bandpass filters, TEST FREQUENCY switch to the limiter input at pin 3, Card 8231. At center frequency, this signal should be from 1.4 to 1.8 times the input level. If the input to the limiter amplifier is normal, change R36, normally approximately 100 ohms, to adjust the low threshold. The high lamp should turn on when the TEST INPUT signal is increasing at a level of from 2.0 to 2.5 V rms when the band-pass filter and its amplifier is operating normally. R50, Card 8231, controls the high signal level threshold.

5-6 DRIFT CALIBRATION

a. Connect the output of a MICOM Model 9100 Test Set to the TEST SIGNAL input BNC connector at approximately 1V rms level, and a DC Voltmeter (HP 3430A or equivalent) to the DRIFT DEMODULATOR output BNC connector. Adjust mechanical zero to DRIFT meter with instrument off. Turn on instrument.

b. Switch the 9100 to 108 kHz and zero deviation, switch the Model 8300 to 108 kHz test frequency, 5 kHz Flutter Bandwidth, FAST DRIFT BW.

c. Switch % FULL SCALE DRIFT to 10% and zero DEMOD output with Zero Set vernier. Switch 9100 modulator to +10% deviation; DRIFT DEMOD output should be +100 ±2 mV and drift meter should read +9.5 to 10.5%. Switch Modulator to -10% duration; output should be -100 ±2 mV and DRIFT meter should read -9.5 to -10.5%.

d. Switch % FULL SCALE to 3% and zero DRIFT DEMOD output with ZERO SET with zero deviation of 9100 modulator, then measure demod output with + and -3% deviation. Output voltage should be +100 ±2 mV and -100 ±2 mV respectively.

e. Check 1, .3, .1, and .03% ranges of the 8200 meter in a similar manner, zeroing the DRIFT DEMOD out with the zero set control for each range. Because of the difficulty of adjusting the output to zero on the .03% range, a span of 200 mV ± 4 mV centered at ± 10 mV from +.03% deviation to -.03% deviation is satisfactory. To minimize rapid drift on the 0.03% range, it may be desirable to place the top cover on the instrument. If all DRIFT DEMOD ranges are in error, check the offset current in the demodulator constant current supply, Q7 Card 8233 as 1.02 ±.01mA, and the adjustment of the precision

QCG capacitor, C9. If these are correct, adjust R75 Card 8233 to provide the best compromise for all ranges. Resistors on S4, % FULL SCALE DRIFT, control the output on the 3%, 1%, 0.3%, 0.1% and .03% ranges. Appropriate selection of R51 will control the output on the 3% range, R50 on the 1% range, R49 on the 0.3% range, R48 on the 0.1% range, and R47 on the .03% range. If the meter is in error, shunting R71 with a selected composition resistor will increase the indication, and shunting the DRIFT meter terminals will decrease the indication.

5-6.1 DRIFT BANDWIDTH

a. Modulate the Model 9100 Test Set at 108 kHz center frequency with a 4 volt peak-to-peak (1.414 rms) sine wave from a Wave-Teck Model 110 or equivalent function generator. Set % Modulation to 1% and set the Model 8300 % FULL SCALE DRIFT sensitivity switch to 1% and DRIFT BW in 30 Hz position.

b. With a HP 400H or equivalent AC voltmeter, measure the DRIFT DEMOD output. The output should be down 3 dB from 100 mV peak-to-peak at from 24 to 36 Hz modulation frequency (voltmeter reading at -3 dB will be 25 mV rms).

c. FAST Drift Meter Bandwidth may be checked by modulating the 9100 Test Set with an 8V peak-to-peak sine wave and noting the frequency at which the meter indicates 71% peak-to-peak deviations. This frequency should be between .56 and .84 Hz. Similarly, the SLOW DRIFT BW should indicate 71% peak-to-peak deviation at from .16 to .24 Hz when the 9100 Test Set is modulated with an 8V peak-to-peak signal.

5-7 FLUTTER TEST AND CALIBRATION

5-7.1 FLUTTER AMPLITUDE

a. Flutter checks are made with the Model 9100 Test Set operated at 108 kHz center frequency, and internally modulated at 100 Hz.

b. With the Model 8300/8300-W turned on and the METER SELECT in EXT FILTER position, adjust the mechanical zero of the flutter-indicator to indicate zero. After adjustment, back off adjusting screw to free meter movement.

c. Connect the output of the Model 9100 Test Set to the SIGNAL INPUT BNC connector of the Model 8300/8300-W, switch the TEST FREQUENCY to 108 kHz, FLUTTER BANDWIDTH to 20 kHz, the PK TIME switch to 2 σ, and the METER SELECT switch to DEMOD. Measure FLUTTER DEMOD output with a HP 400H or equivalent VTVM.

d. With 10% modulation and the % PEAK-TO-PEAK flutter switch at 10%, the FLUTTER DEMOD output should be 100 mV ±2 mV peak-to-peak (34.7 to 36.1 mV rms). Check each sensitivity range with corresponding % modulation and % PEAK-TO-PEAK flutter sensitivity. The FLUTTER DEMOD output should be 100 mV ±2 mV peak-to-peak on each range except on the .01% range where instrument noise and system noise will result in a higher reading.

e. If all ranges are in error, adjust R6, the input resistor of the DRIFT amplifier on Card 8233. If the 10%, 3%, 1% and 0.3% ranges have the same percentage error, replace R4 on S6, the % PEAK-TO-PEAK flutter sensitivity switch. If a particular range is in error more than 2%, replace the appropriate resistor on S6. R1 controls the .01% range, R2 and .03% range, R3 the 0.1% range, R4 the 0.3% and higher ranges; R8 controls the 10% range, R7 the 3% range, and R6 the 1% range.

5-7.2 FLUTTER BANDWIDTH

a. Modulate the Model 9100 Test Set at a 108 kHz center frequency with a HP 651A (or equivalent) wideband oscillator. Place the flutter % PEAK-TO-PEAK switch in the 1% position. For convenience and increased accuracy, it is permissible to measure the flutter DEMOD OUTPUT at a higher level than 100 mV peak-to-peak. It is recommended that the 9100 Test Set be modulated with a signal which produces zero dB output on the HP 400H (or equivalent VTVM) on its 300 mV rms range at 100 Hz.

b. Switch FLUTTER BANDWIDTH to 20 kHz. With 100 Hz as reference, the FLUTTER DEMOD OUTPUT should be ± 0.5 dB from 2 Hz to 60% of filter bandwidth (12 kHz). The response should vary by less than ±1 dB between 60% of bandwidth (12 kHz) and 80% of bandwidth (16 kHz), and should be 3 dB down at full bandwidth (20 kHz) ± 5%. Frequency response of all filters shall be the same in terms of filter bandwidth. That is:

FILTER	±0.5 dB to 0.6 BW	±1 dB to 0.8 BW	-3 dB at BW ± 5%
20 kHz	12 kHz	16 kHz	19.0 to 21.0 kHz
10 kHz	6 kHz	8 kHz	9.5 to 10.5 kHz
5 kHz	3 kHz	4 kHz	4.75 to 5.25 kHz
2.5 kHz	1.5 kHz	2 kHz	2.38 to 2.63 kHz
1.25 kHz	750 Hz	1 kHz	1.19 to 1.31 kHz
0.625 kHz	375 Hz	500 Hz	59[illegible] to 656 Hz
0.313 kHz	188 Hz	250 Hz	297 to 329 Hz

Switch FLUTTER BANDWIDTH to each position, and check filter frequency response.

c. At 100 Hz modulating frequency, the output should change less than ±.1 dB when switched through all FLUTTER BANDWIDTH positions.

d. If the frequency response of the Flutter Bandwith filters are outside specifications, refer to Section 4-15, Circuit Description of the Low-Pass Filter-Cards 8234-1 and 8334 and to Section 6, Schematics 8234-1 and 8334 for trouble-shooting information.

5-7.3 FLUTTER INDICATOR CALIBRATION

a. Modulate the Model 9100 Test Set with a 100 Hz 4V peak-to-peak signal at 108 kHz center frequency, switch % modulation to 1%.

b. Set Model 8300/8300-W to 108 kHz TEST frequency, 20 kHz FLUTTER BANDWIDTH, 1% FLUTTER PEAK-TO-PEAK, and 2 σ PK TIME, and meter select to DEMOD.

c. Flutter indicator should read from 95% to 105% full scale. If outside this range, check FLUTTER DEMOD OUTPUT as between 34.7 and 36.1 mV. If outside this tolerance, recalibrate. If within this tolerance, switch METER SELECT to EXT FILTER: FLUTTER DEMOD OUTPUT should be between 1.17 and 1.23 volts peak-to-peak. If outside this range, adjust R30, Card 8235, to bring to 1.2V peak-to-peak. When FLUTTER DEMOD output is from 1.17 to 1.23V peak-to-peak with METER SELECT in the EXT FILTER position, switch METER SELECT to DEMOD and check flutter indicator. If indicator reads less than 95% full scale, shunt R63, a 4.32 kilohm precision resistor, on the statistical peak reading voltmeter Card 8236, with a selected composition resistor to bring within tolerance. If the meter reads more than 105% of full scale, shunt M2, the 200 μA FLUTTER indicator input terminals with a selected composition resistor to bring the reading within tolerance.

5-7.4 LOW FREQUENCY CUTOFF

a. Modulate Model 9100 Test Set with Wave-teck Model 110 function generator (or equivalent) with a sine wave. Set center frequency at 108 kHz and % modulation 1%. Set Model 8300/8300-W to 108 kHz TEST FREQUENCY, FLUTTER BANDWIDTH to 20 kHz, % PEAK TO PEAK flutter to 1%. Adjust function generator level at 100 Hz for full scale on flutter meter. Reduce frequency of function generator until peak Flutter indication is 71% of full scale. This frequency should be less than 0.3 Hz. If outside this range, look for an out-of-tolerance coupling capacitor C1, C11, or C4 on flutter amplifier card 8235.

5-8 STATISTICAL VOLTMETER CHECK

a. Modulate the Model 9100 Test Set with a triangular wave at 100 Hz and approximately 4V peak-to-peak amplitude from a Wavetek 110 function generator. Set center frequency to 108 kHz and 1% modulation. Set Model 8300/8300-W to 108 kHz TEST FREQUENCY, flutter % PEAK TO PEAK to 1%, FLUTTER BANDWIDTH to 20 kHz.

b. With the PK TIME in the 3 σ position, adjust the Model 110 function generator level to deflect the Flutter indicator to 100%. When the PK time switch is changed to 2 σ, the flutter indicator should move to 94% to 96%, and when the PK TIME switch is moved to 1 σ, the flutter indicator should move to 65% to 72%. If the indications are outside the given tolerances, reference to Section 4-16 and the schematic for the Statistical Peak Reading Voltmeter (8236) will permit locating the out-of-tolerance component causing the error.

5-9 WAVE ANALYZER TEST (8300-W only)

a. The wave analyzer may be tested independently of the Demodulator portion of the instrument by coupling the test signal to the EXT INPUT BNC connector of the Model 8100-W, and switching the FLUTTER BANDWIDTH switch to METER INPUT. Use a frequency counter (HP Model 5223L or equivalent) to measure accurately frequency of a Wavetek 110 function generator winewave output. Place the FLUTTER % PEAK TO PEAK switch to 10%, and the METER SELECT switch in the X100 position.

b. With the function generator at 200 Hz, tune the Hz dial carefully to position near 2 that produces the maximum flutter indication. Adjust input to make maximum response at 200 Hz 100% on meter. Then find frequencies of 71% indication at between 209 to 211 Hz and 189 to 191 Hz. If the 3 db response is outside tolerance, adjust R38, 15 turn wire-wound pot, to produce a 10% 3 dB bandwidth. Note that if the bandwidth is narrowed, the input must also be lowered to produce the same peak deflection of the meter.

c. Switch the METER SELECT to DEMOD and adjust the input to cause a deflection of 90% on the Flutter indicator at 200 Hz.

d. Measure the peak response of the wave analyzer at 50 Hz, 200 Hz, and 500 Hz on the X100 wave analyzer range; at 500 Hz, 2 kHz, and 5 kHz on the X1K range; at 5 kHz and 20 kHz on the X10K range; at 5 Hz, 20 Hz and 50 Hz on the X10 range; at .5 Hz, 2 Hz, and 5 Hz on the X1 range. Take time to find maximum response on the X1 range.

e. The peak response should be between 75% and 105% for all measurements. If all ranges are high or

low, replace selected shunt resistor in parallel with R4, Card 8238, to adjust the gain of the Wave Analyzer. If the high frequency end of all bands is high, reduce the value of the selected shunt resistor in parallel with R22, 825 ohm precision resistor, on card 8238 and conversely. If the R22 shunt resistor is changed, readjust R38 to provide the same peak response at 200 Hz as obtained before the change to preserve the bandwidth adjustment. If the low frequency end response on all bands is high, add shunt resistor (in .5 meg to 2 meg range) across terminals 1 and 3 R2A, ganged pot on panel, adjusted by Hz dial. If low frequency end response of all ranges is low, shunt R2B terminals 1 and 3 with a high value resistor to bring response within tolerarance. Some compromise may be necessary to equalize the response over the entire tuning range.

SECTION VI

SCHEMATICS

6-1 SCHEMATIC DIAGRAMS

6-1.1 This section contains the schematic diagrams necessary for maintenance and calibration of the Model 8300/8300-W Flutter Meters. Each diagram illustrates the circuits on each plug-in card and all associated switches, switch assemblies, connectors, and related components.

6-1.2 The following conventions are used on all drawings:

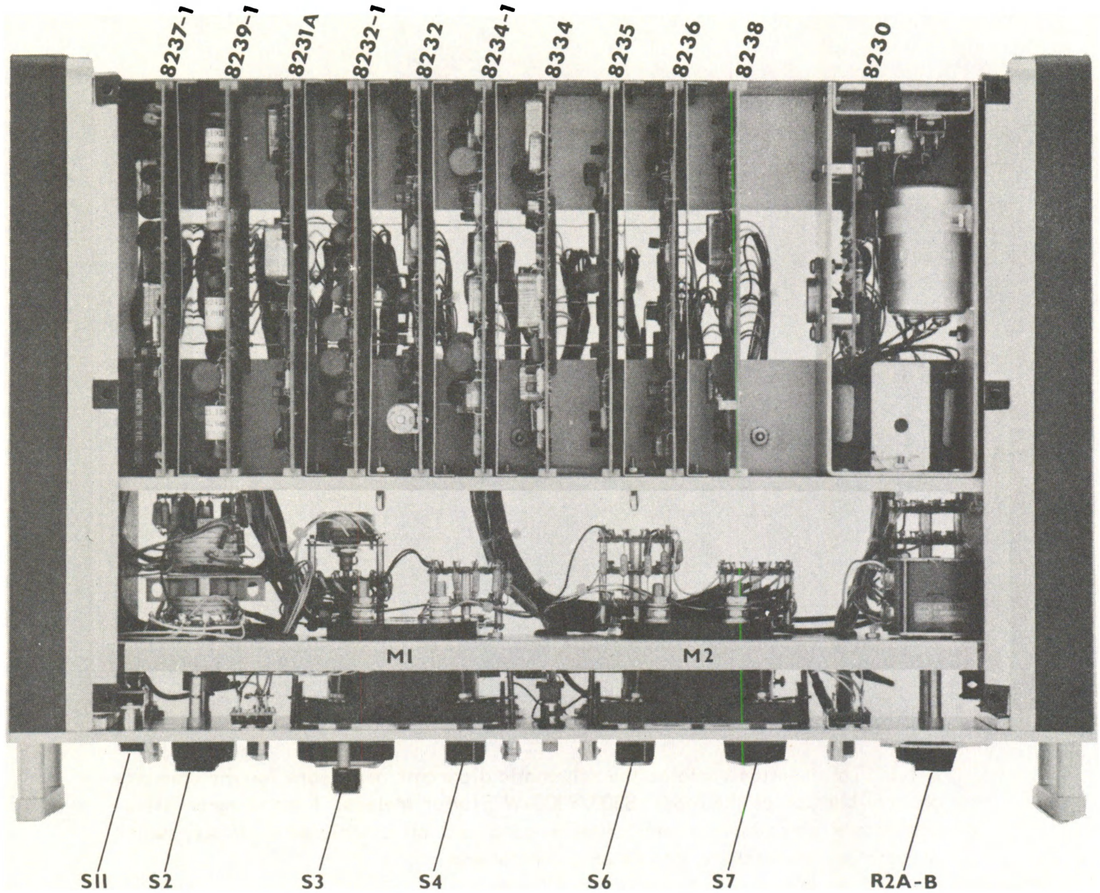
1. Components mounted on the card are enclosed within a dotted outline.

2. Front panel designations are enclosed within a box:

   $\boxed{\text{TEST FREQUENCY}}$

3. Component values marked ▲ are nominal, optimum values selected at factory, or may be omitted.

6-2 Figure 6-1 on page 6-2 shows the location of all cards, connectors, and controls in the package.



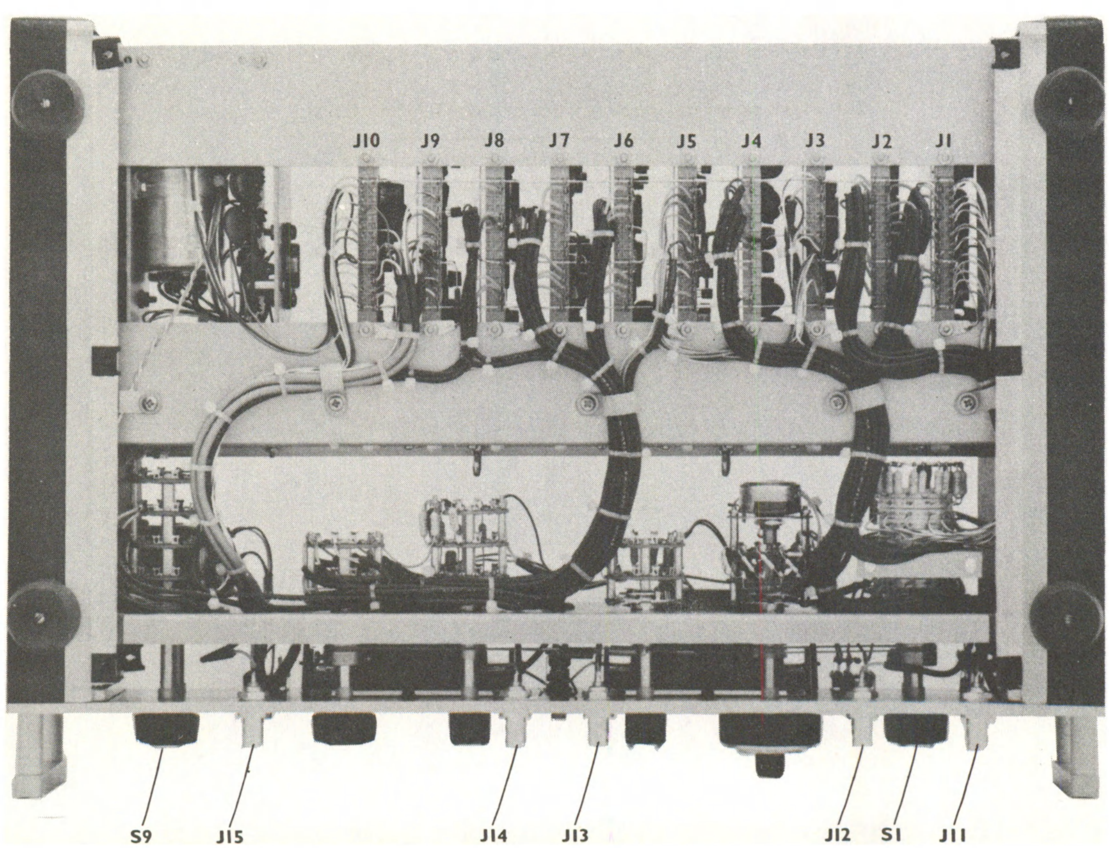
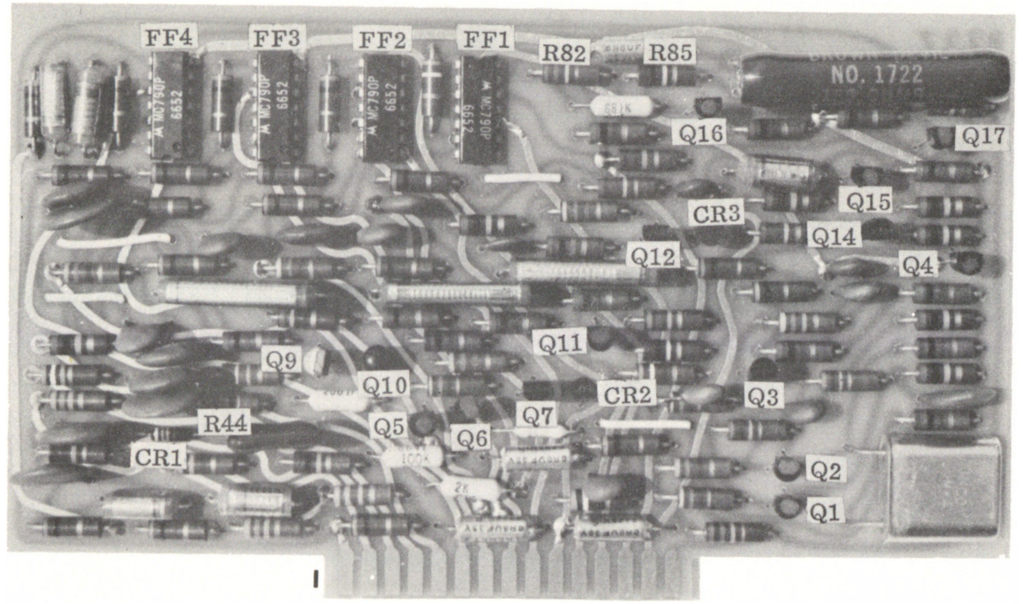
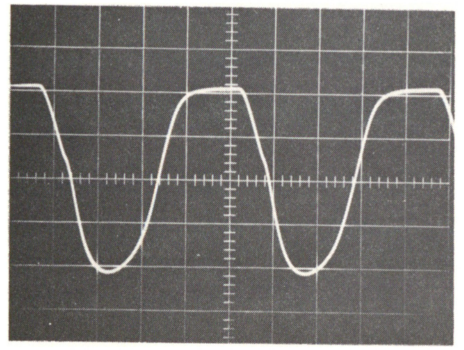


FIGURE 6 - 1 COMPONENT LOCATION

8237-1



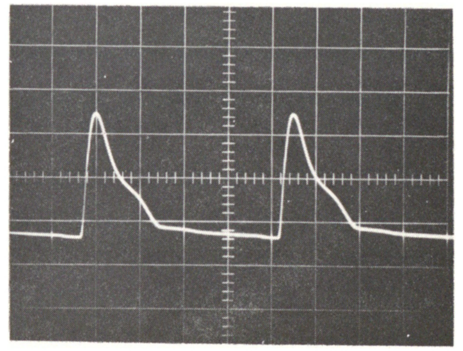
A



2V/div

1μ sec/div

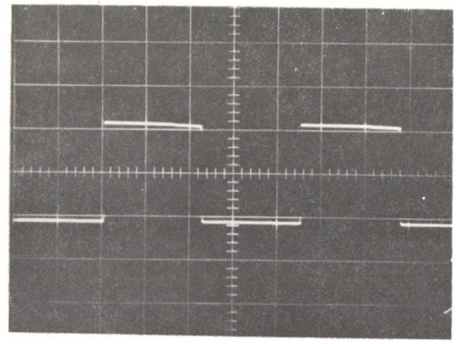
B



1V/div

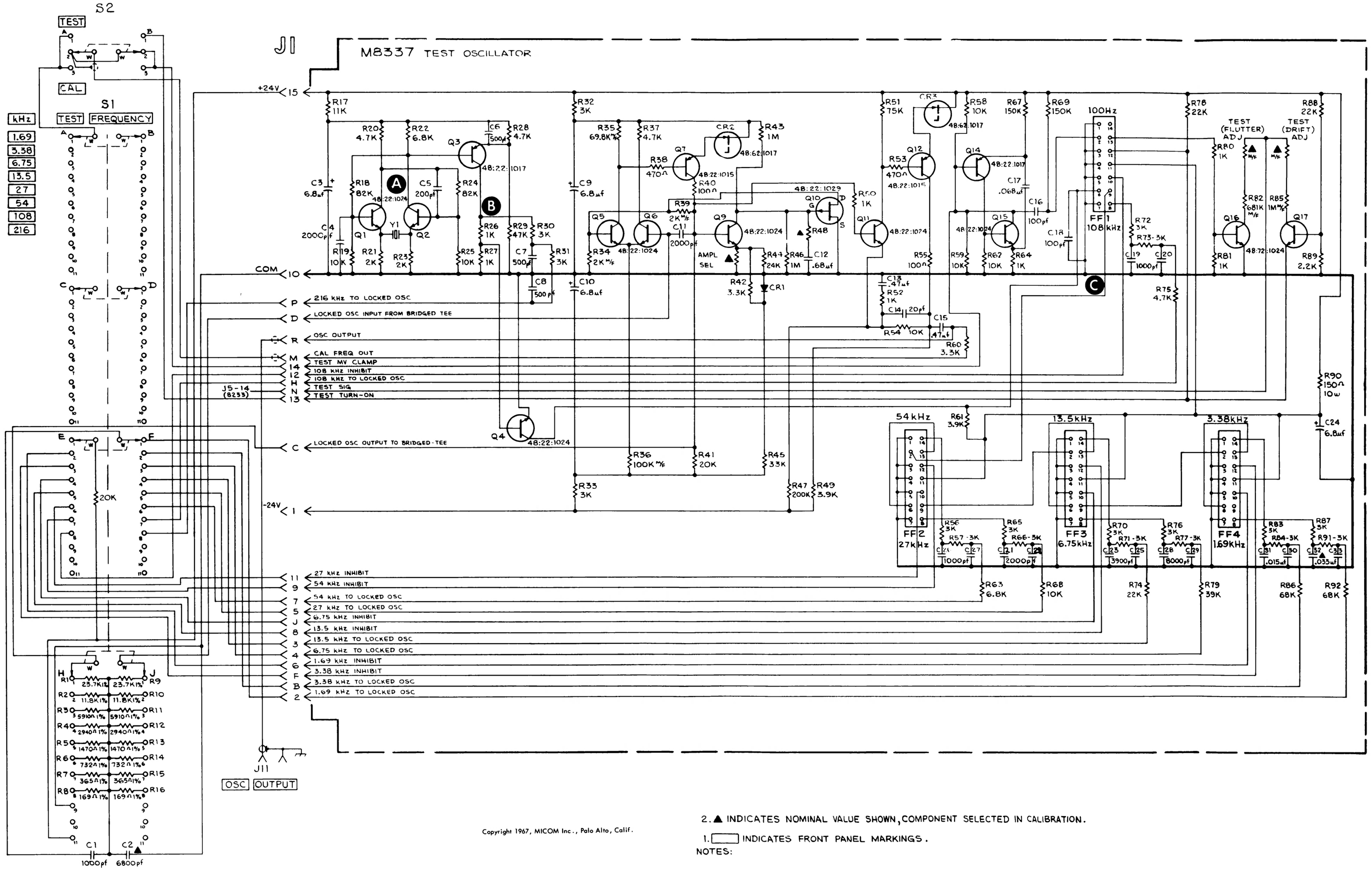
1μ sec/div

C



1V/div

2μsec/div



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NOTES:

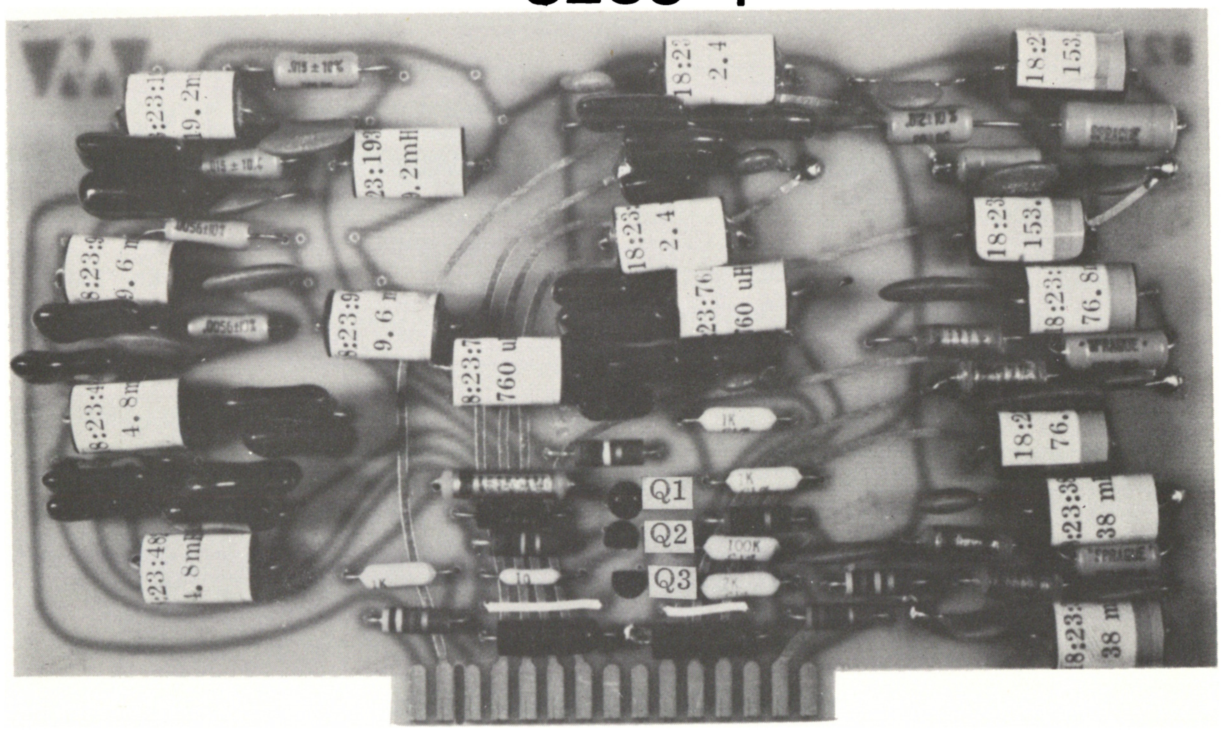
1. ▭ INDICATES FRONT PANEL MARKINGS.

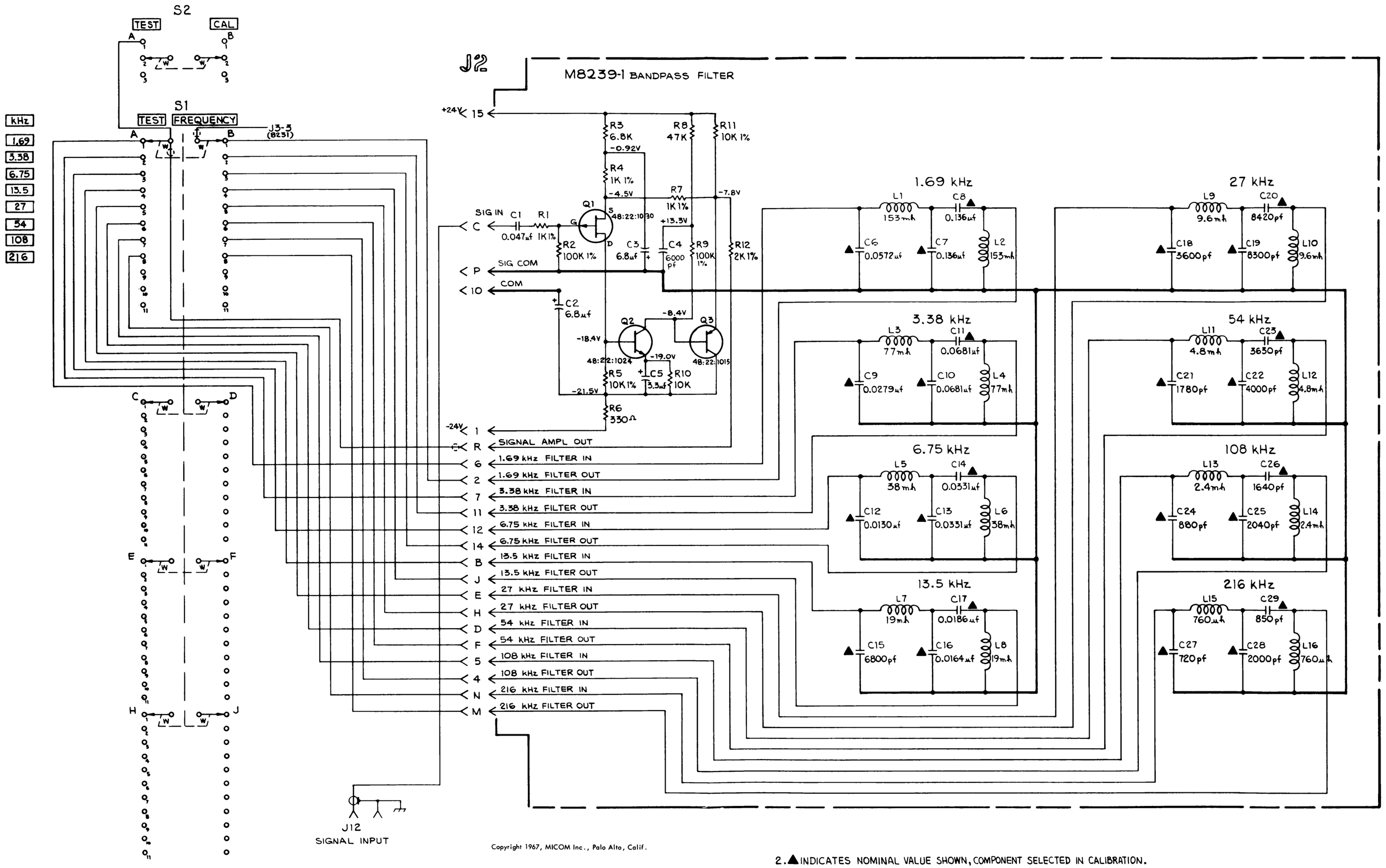
2. ▲ INDICATES NOMINAL VALUE SHOWN, COMPONENT SELECTED IN CALIBRATION.

Figure 6-2 Card 8237

TEST OSCILLATOR

8239-1





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2. ▲ INDICATES NOMINAL VALUE SHOWN, COMPONENT SELECTED IN CALIBRATION.

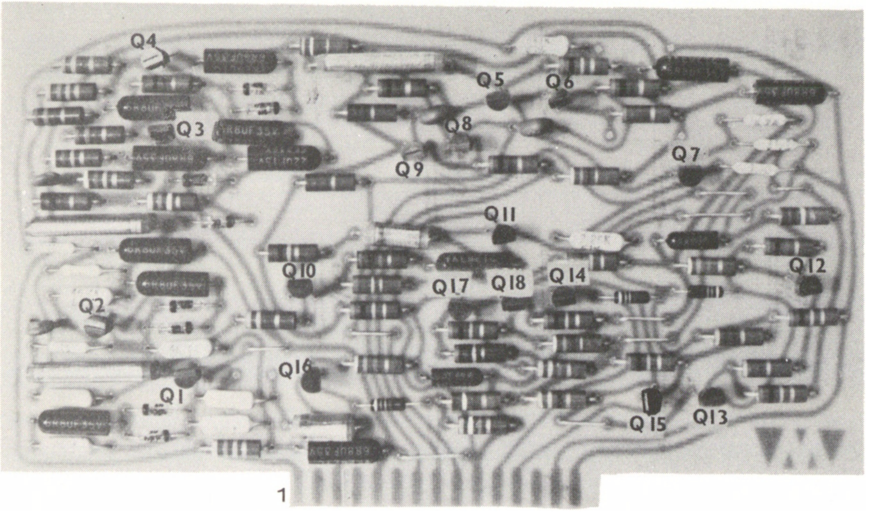
1. ☐ INDICATES FRONT PANEL MARKING.

NOTES:

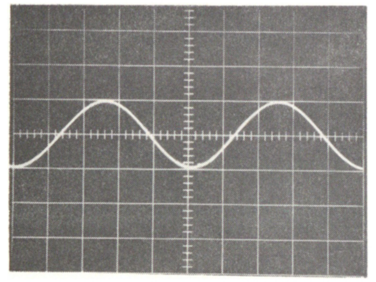
Figure 6 - 3 Card 8239

BANDPASS FILTERS

8231A



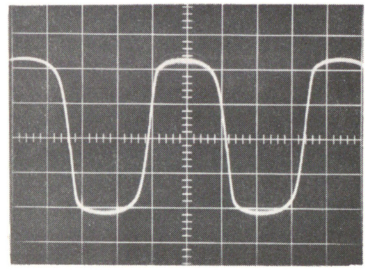
A



50mV/div

2μsec/div

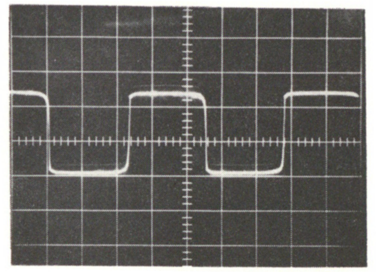
B



.2V/div

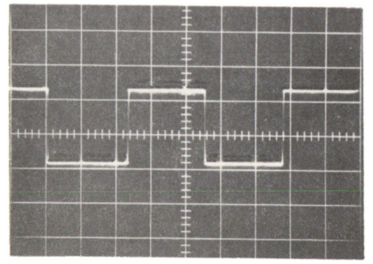
2μ sec/div

C



2μsec/div

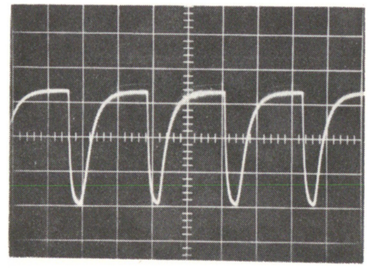
D



.5V/div

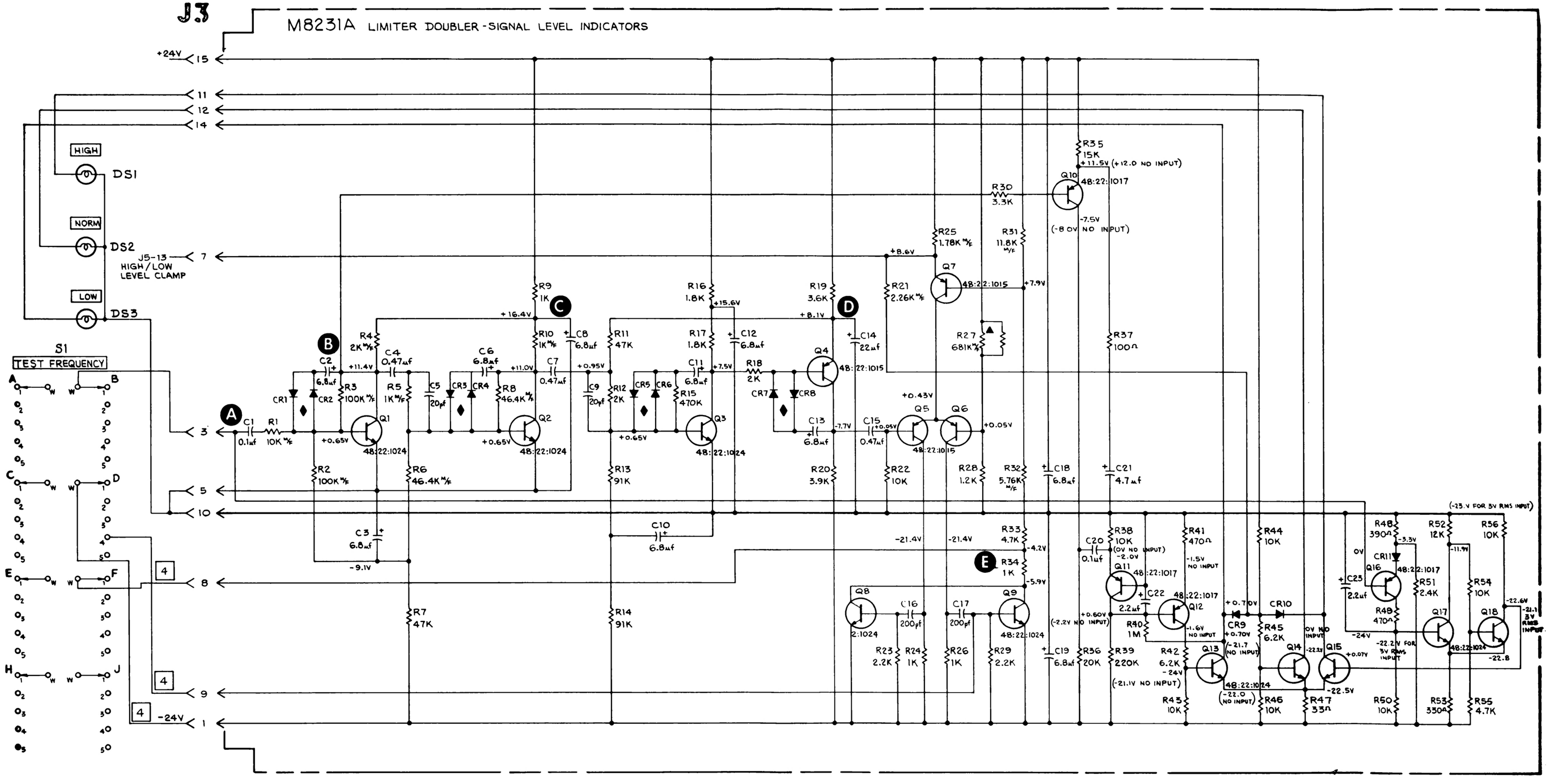
2μ sec/div

E



5V/div

2μ sec/div



4 ON THE 8300 S1 IS CHANGED TO AN 8 POLE 11 POSITION SWITCH. ROUTE THE FOLLOWING WIRES AS SHOWN: J3-1 TO S1-C-W, J3-9 TO S1-C-8 AND J3-8 TO S1-D-W

3. ☐ INDICATES FRONT PANEL MARKING.

2. ♦ INDICATES DIODE SELECTED FOR VOLTAGE DROP.

1. ▲ INDICATES NOMINAL VALUE SHOWN, COMPONENT SELECTED IN CALIBRATION.

NOTES:

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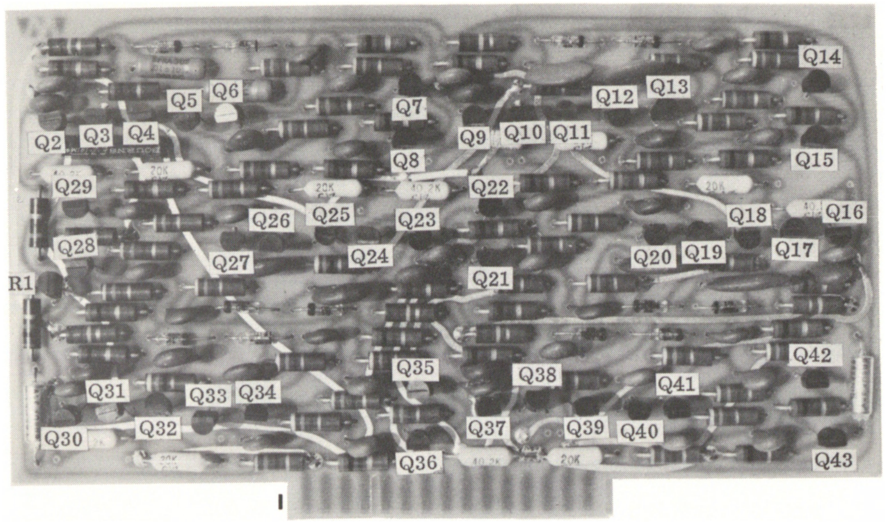
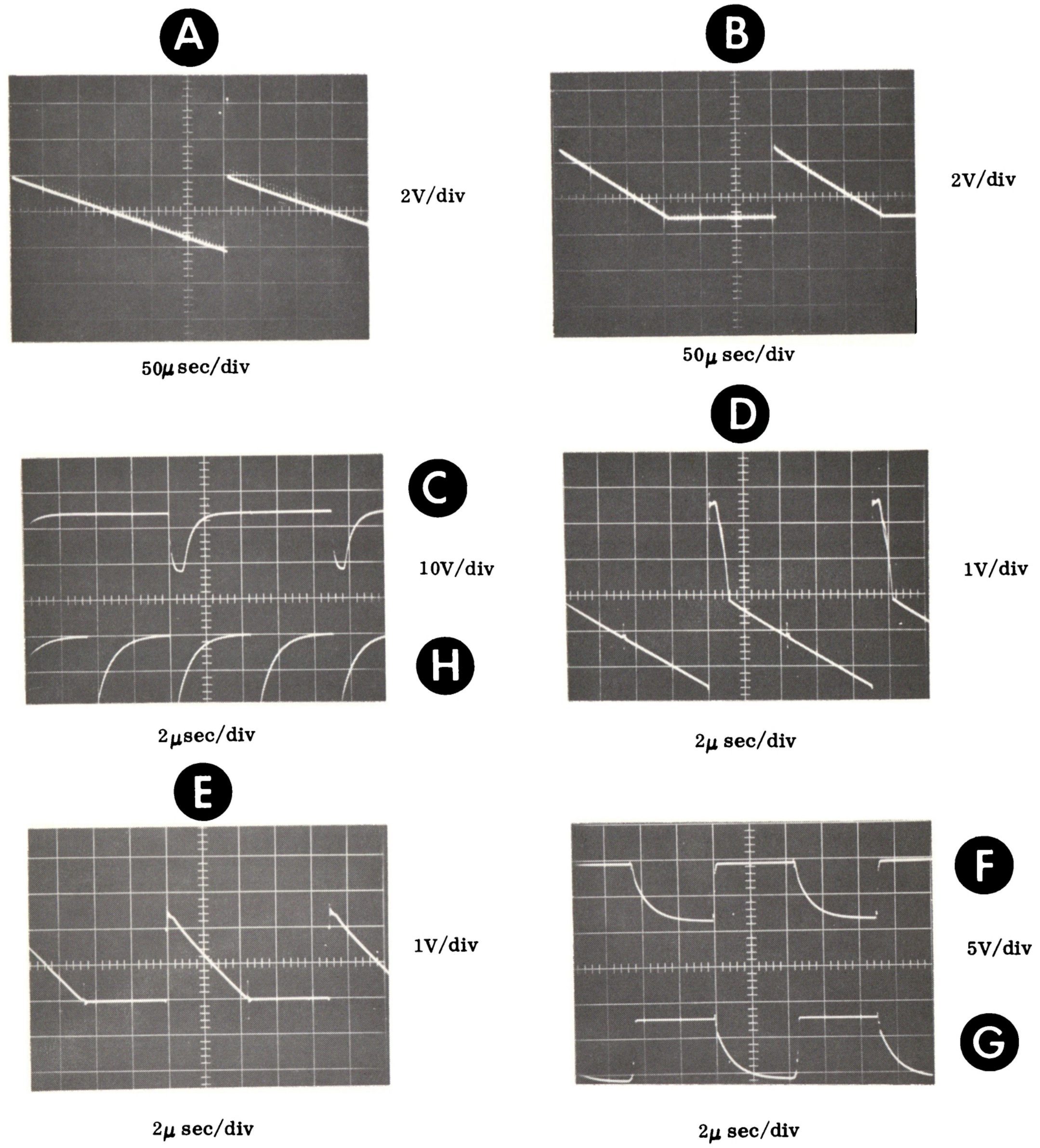
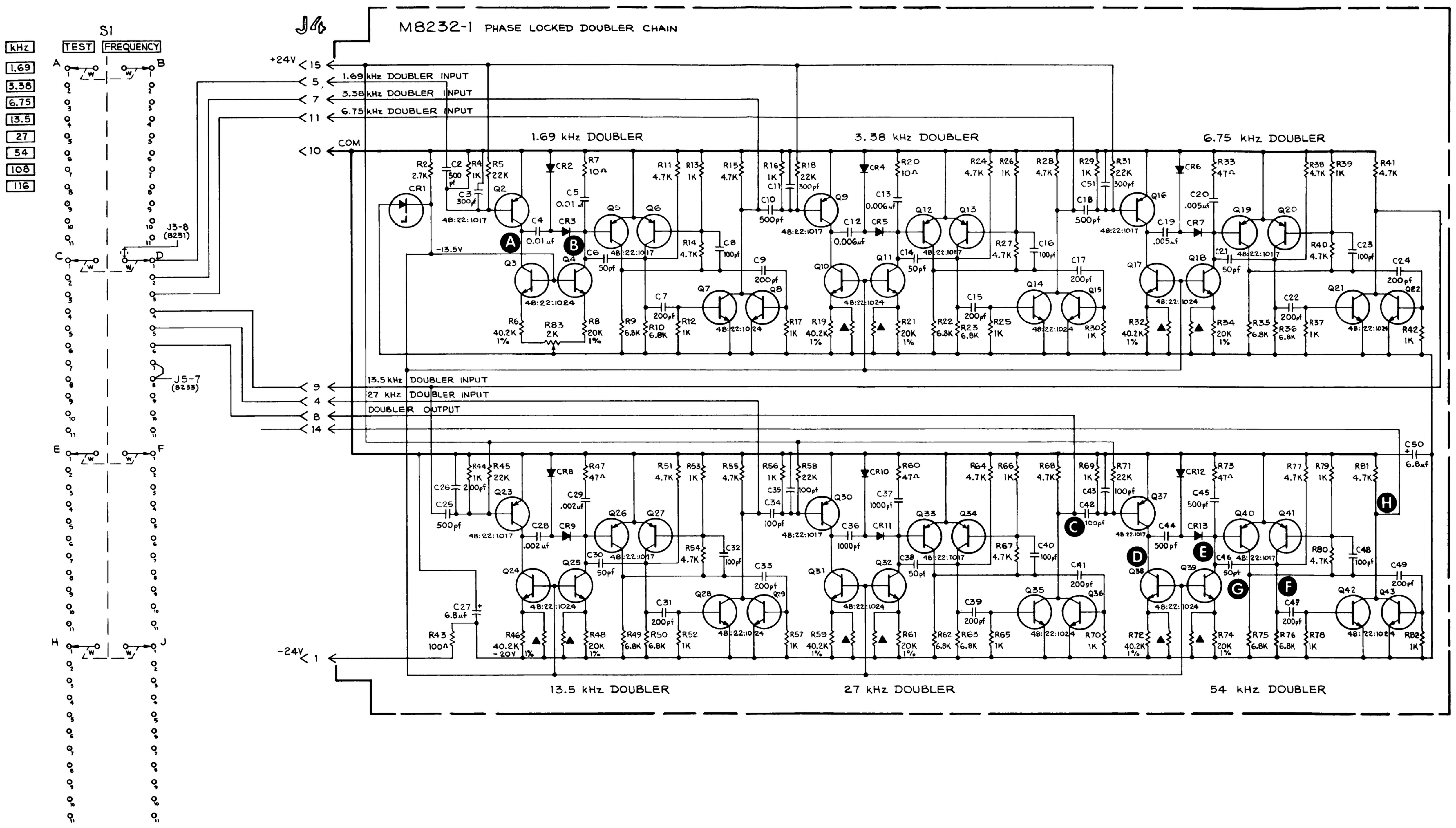
Figure 6 - 4 Card 8231A

LIMITER-DOUBLER, SIGNAL LEVEL INDICATORS

8232-1







3 DOUBLER DESIGNATIONS ARE TEST INPUT FREQUENCIES. ACTUAL DOUBLER INPUT IS TWICE TEST INPUT FREQUENCY.

2. ☐ INDICATES FRONT PANEL MARKING.

1. ▲ INDICATES COMPONENT SELECTED IN CALIBRATION.

NOTES:

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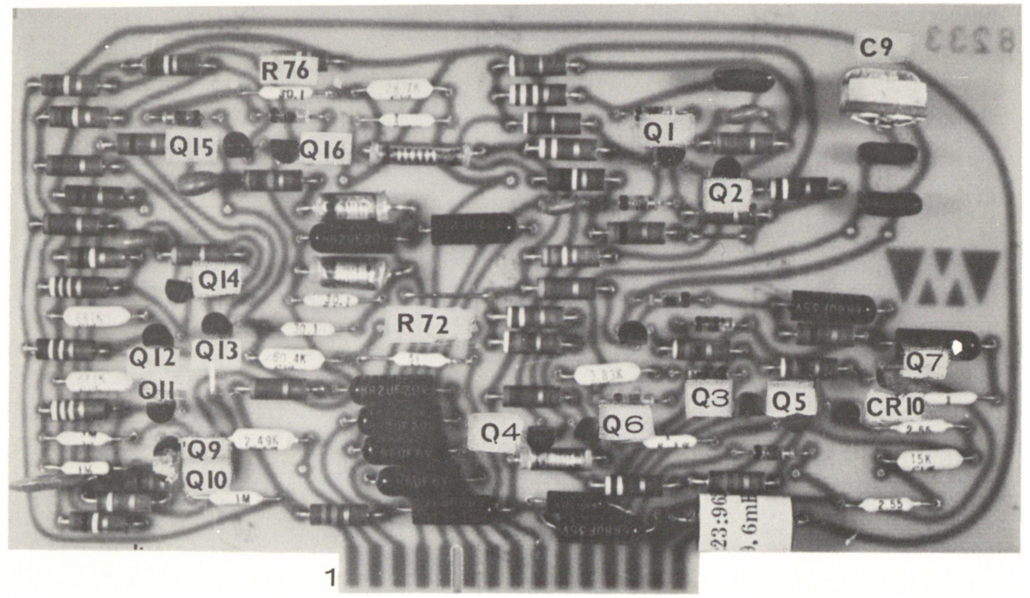
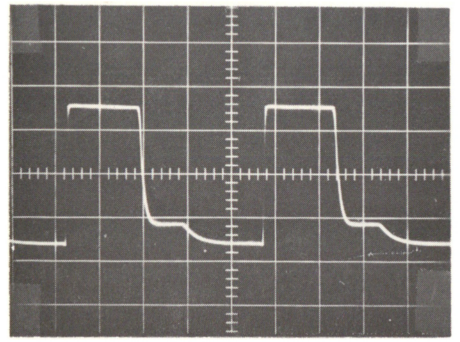
Figure 6 - 5 Card 8232

PHASE LOCKED DOUBLERS

8233



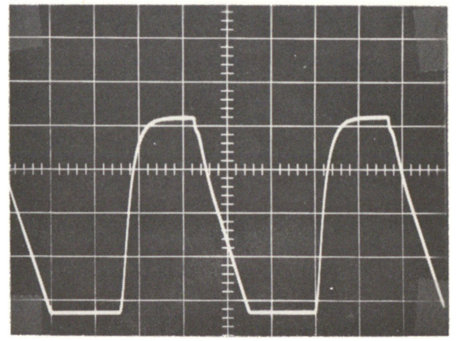
A



2V/div

1μsec/div

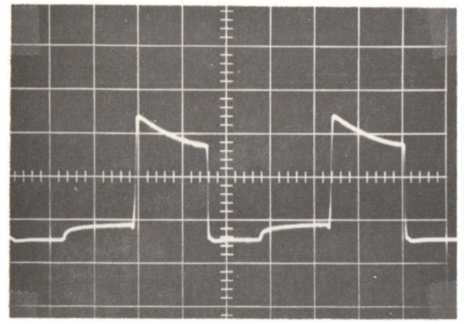
B



5V/div

1μsec/div

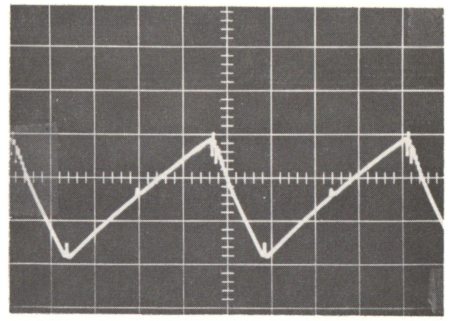
C



.5V/div

1μsec/div

D



0.2V/div

1μsec/div

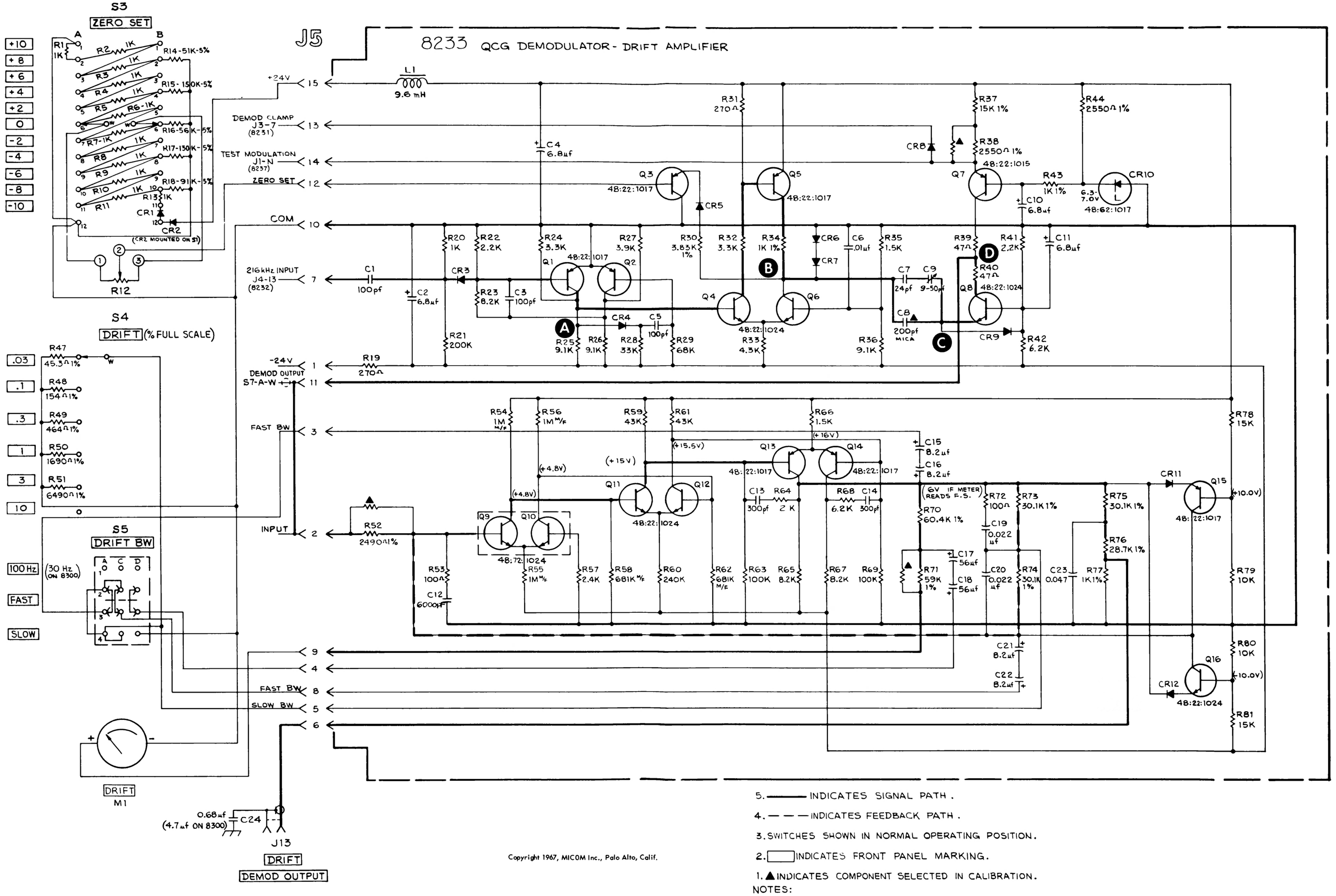


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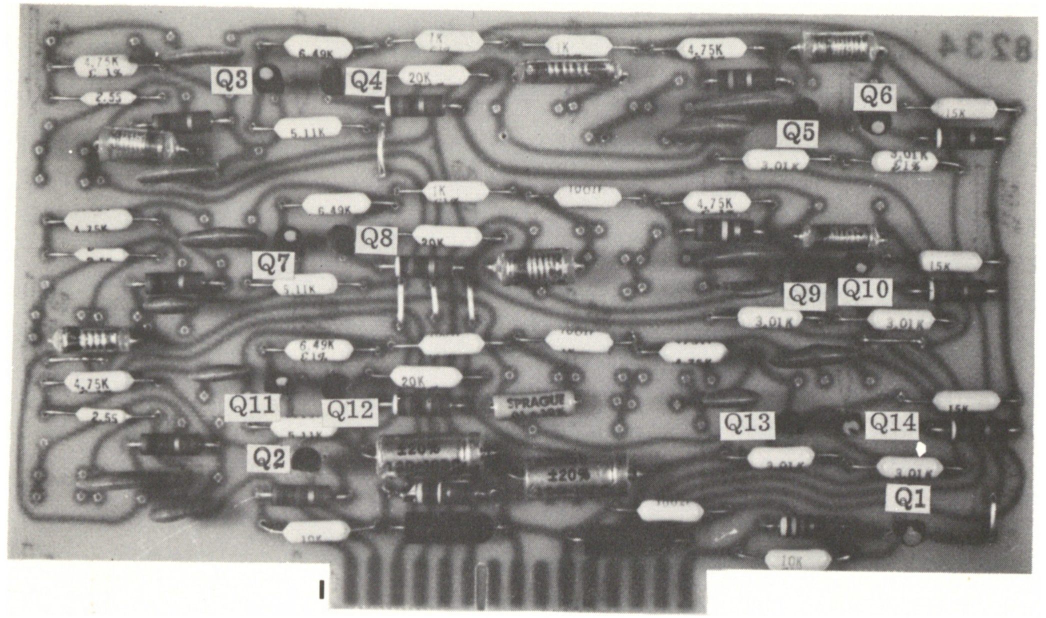
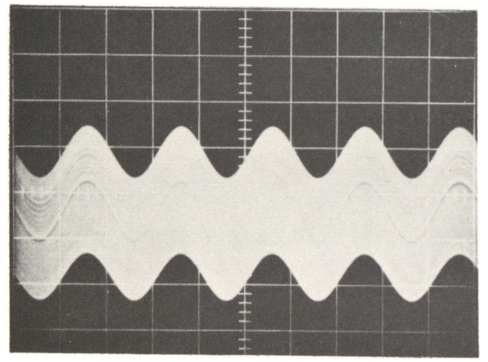
Figure 6 - 6 Card 8233

QCG DEMODULATOR-DRIFT AMPLIFIER

8234-1



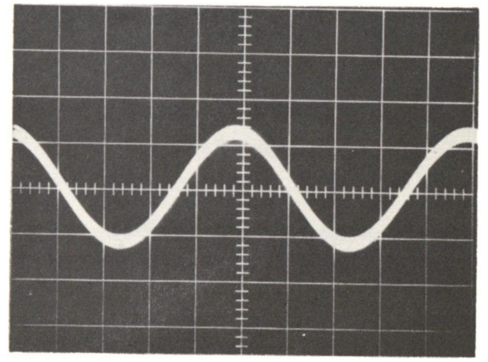
A



.2V/div

500μ sec/div

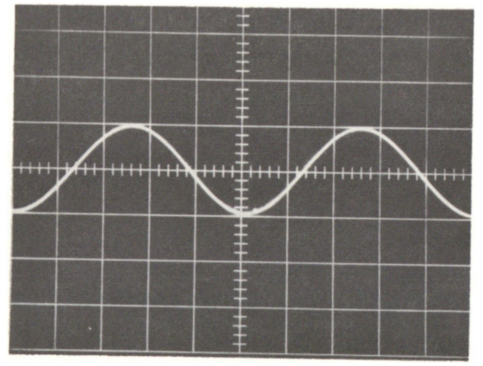
B



2V/div

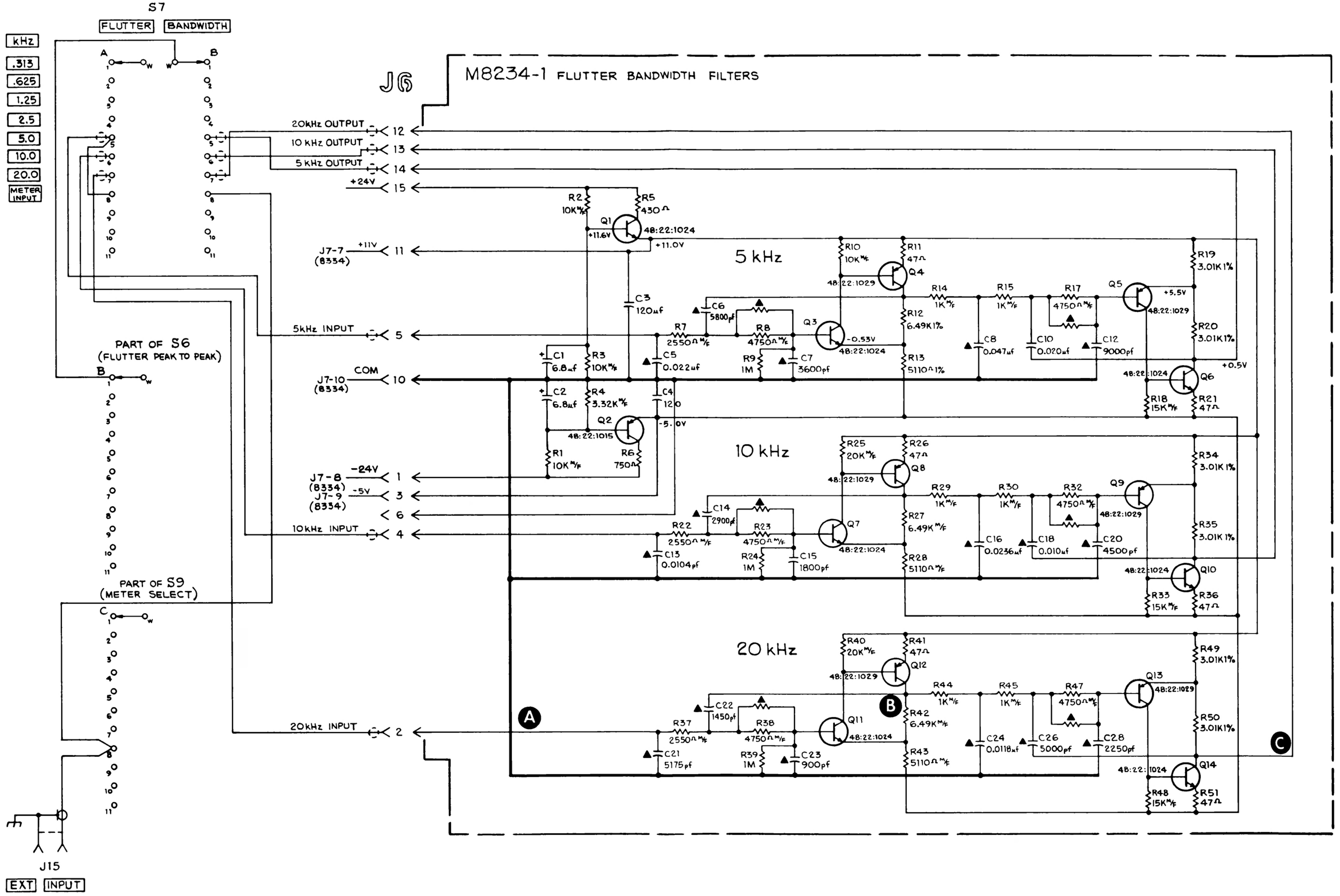
200μ sec/div

C



.4V/div

200μsec/div



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NOTES:

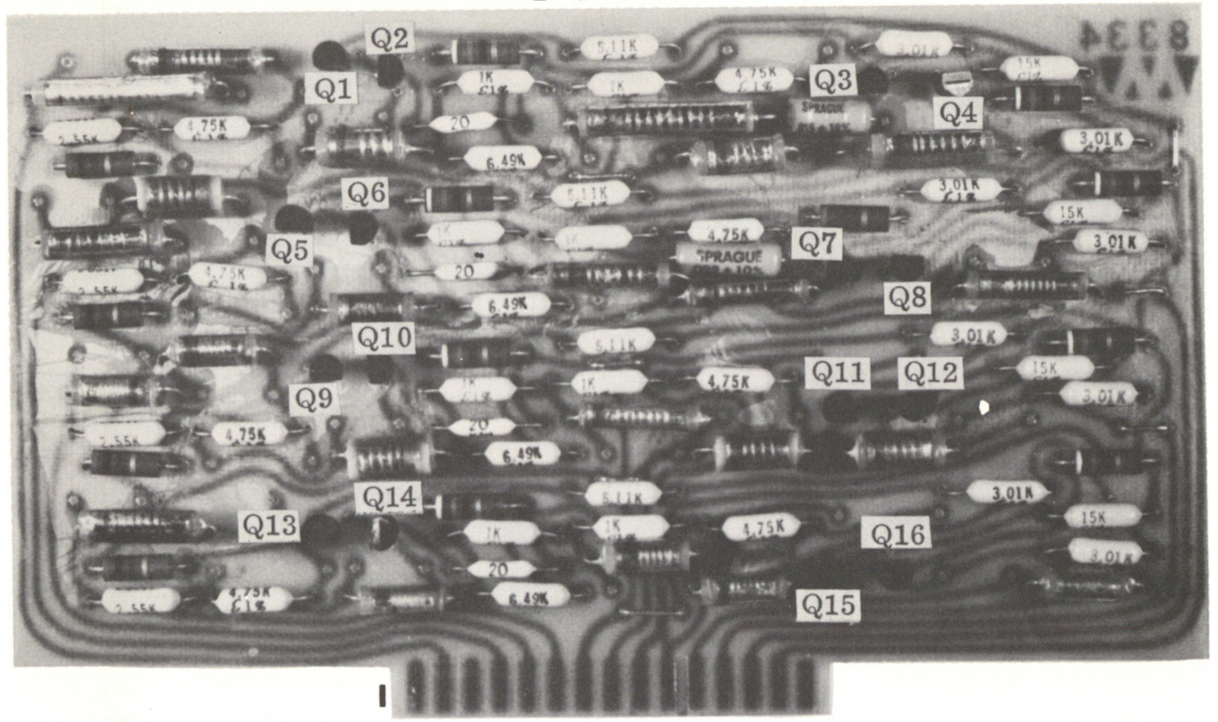
1. ▲ INDICATES NOMINAL VALUE, COMPONENT SELECTED IN CALIBRATION

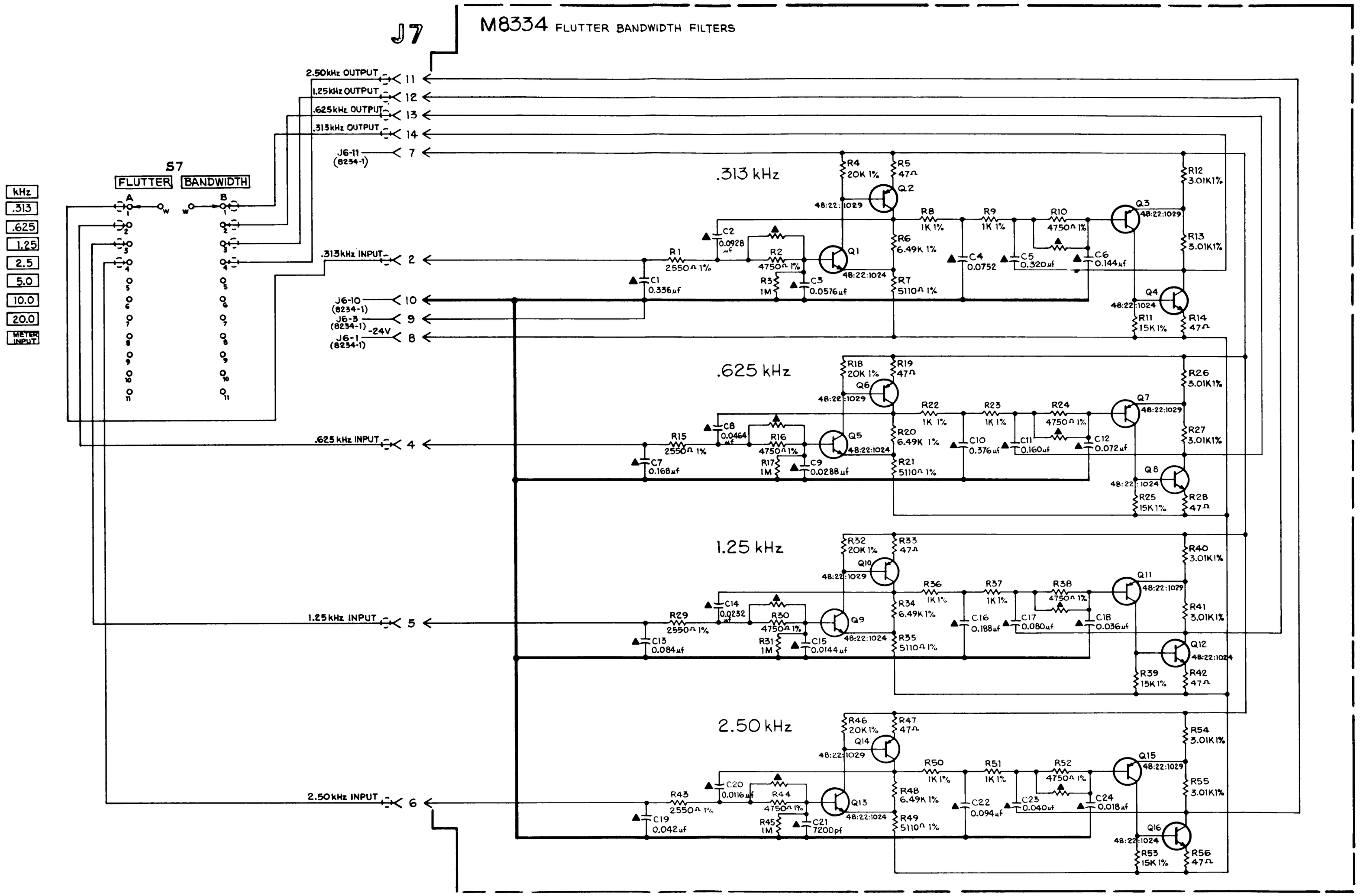
2. ▭ INDICATES FRONT PANEL MARKING

Figure 6 - 7 Card 8234

FLUTTER BANDWIDTH FILTERS

8334





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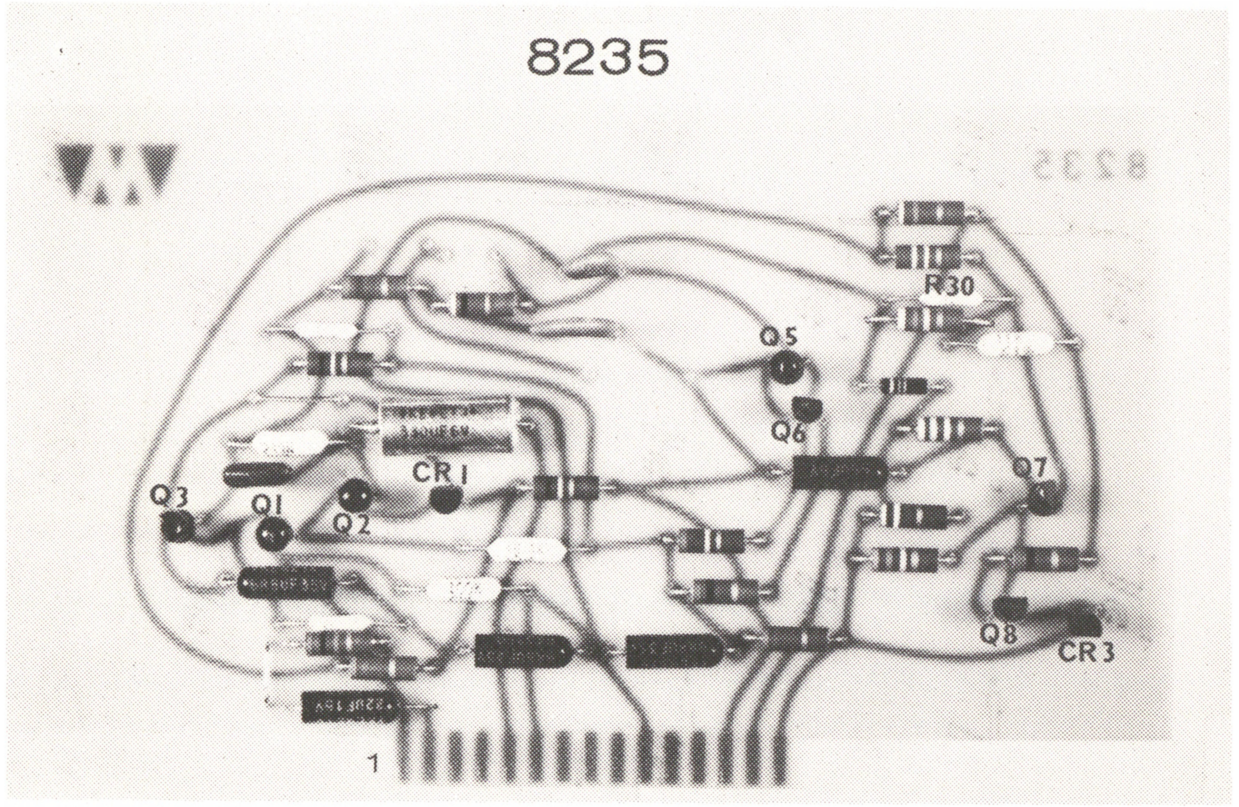
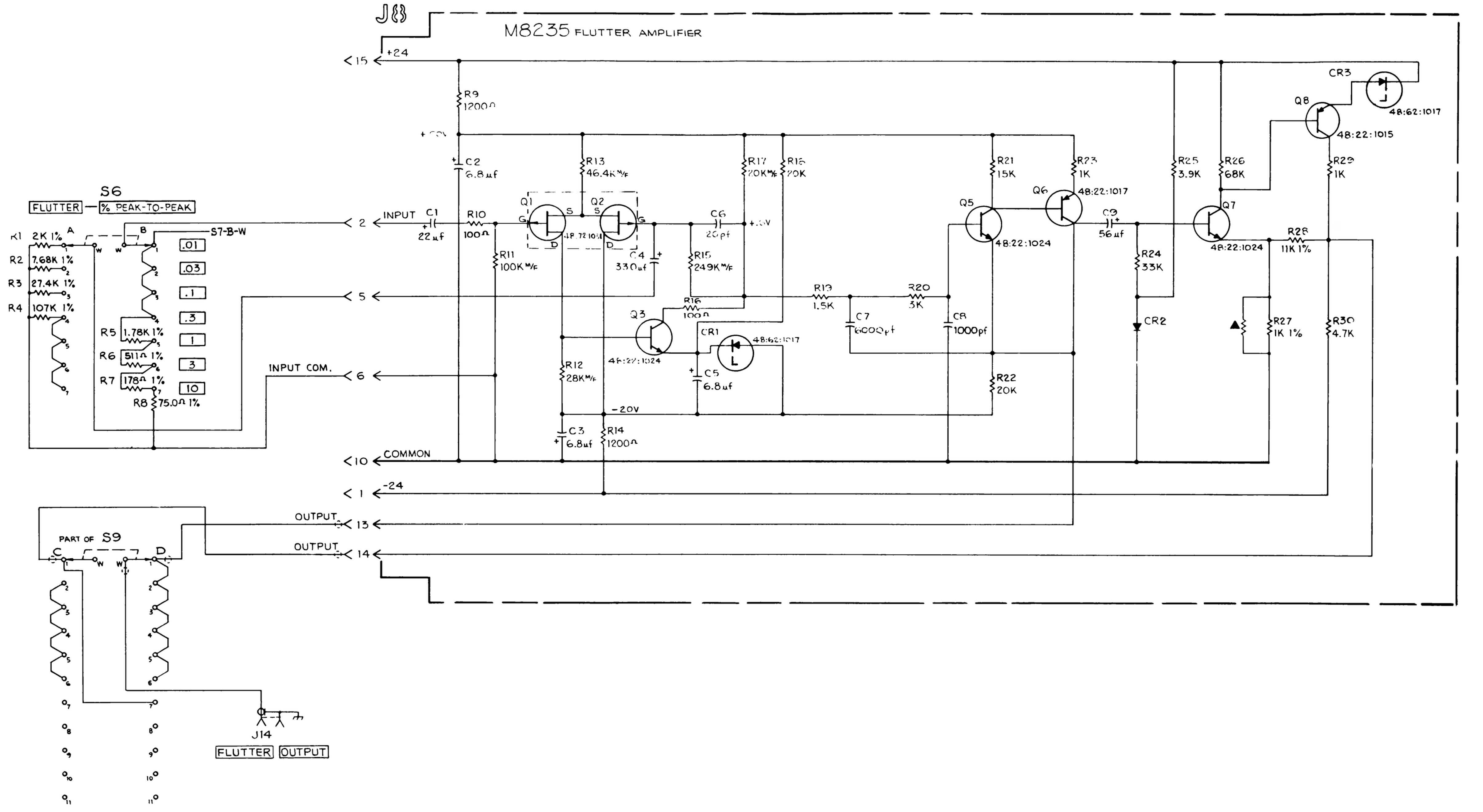
NOTES:

1. ▲ INDICATES NOMINAL VALUE, COMPONENT SELECTED IN CALIBRATION.
2. ▭ INDICATES FRONT PANEL MARKING.

Figure 6-7A Card M8334

FILTER BANDWIDTH FILTERS





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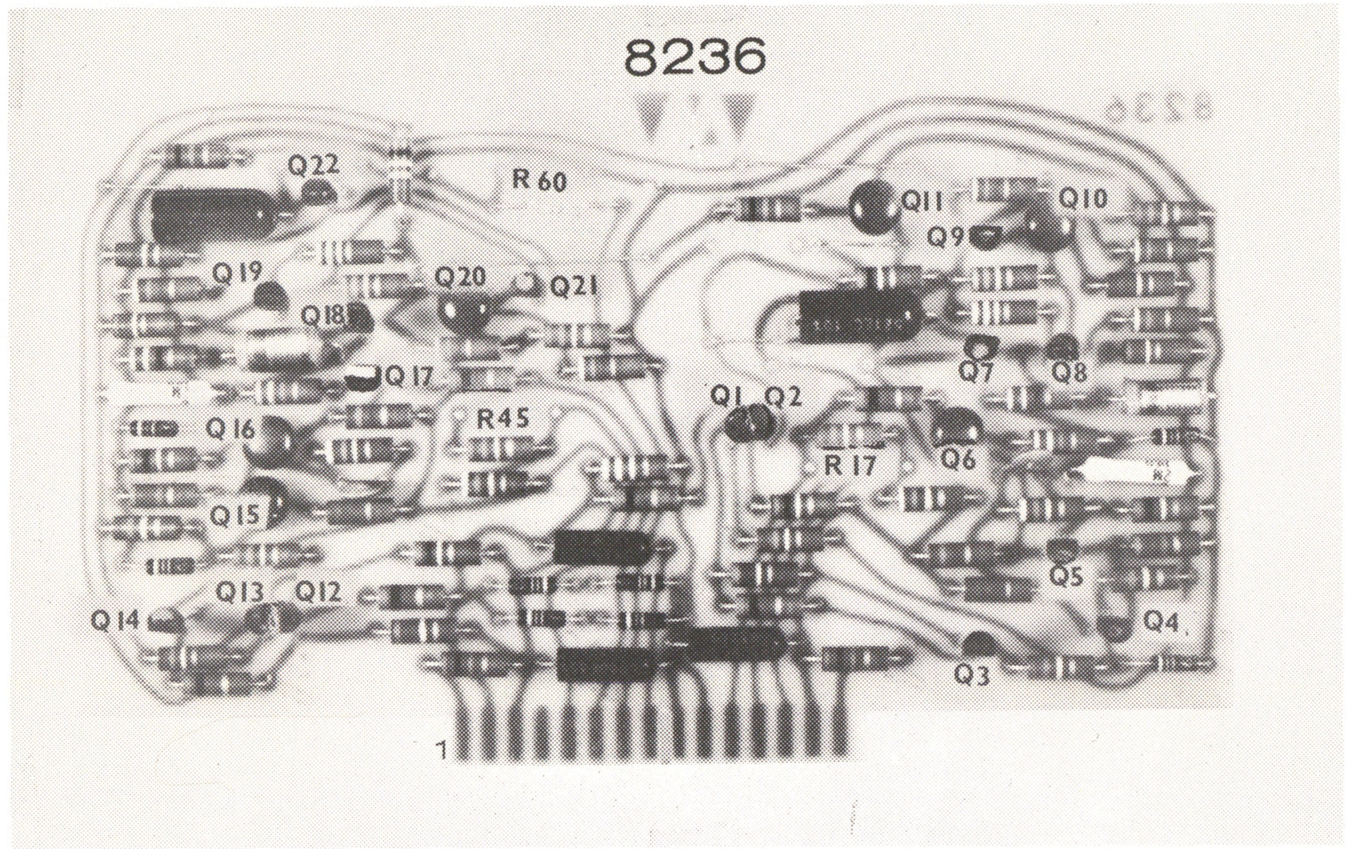
NOTE:

1. ☐ INDICATES FRONT PANEL MARKING.

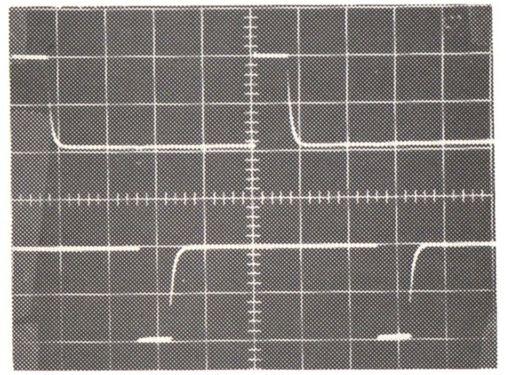
2. ▲ INDICATES COMPONENT SELECTED IN CALIBRATION.

Figure 6 - 8 Card 8235

FLUTTER AMPLIFIER



1σ



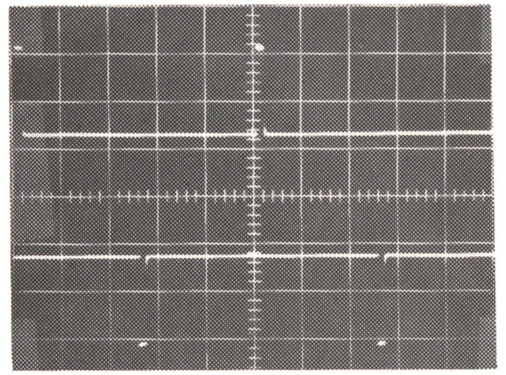
B

5V/div

A

200μsec/div

2σ

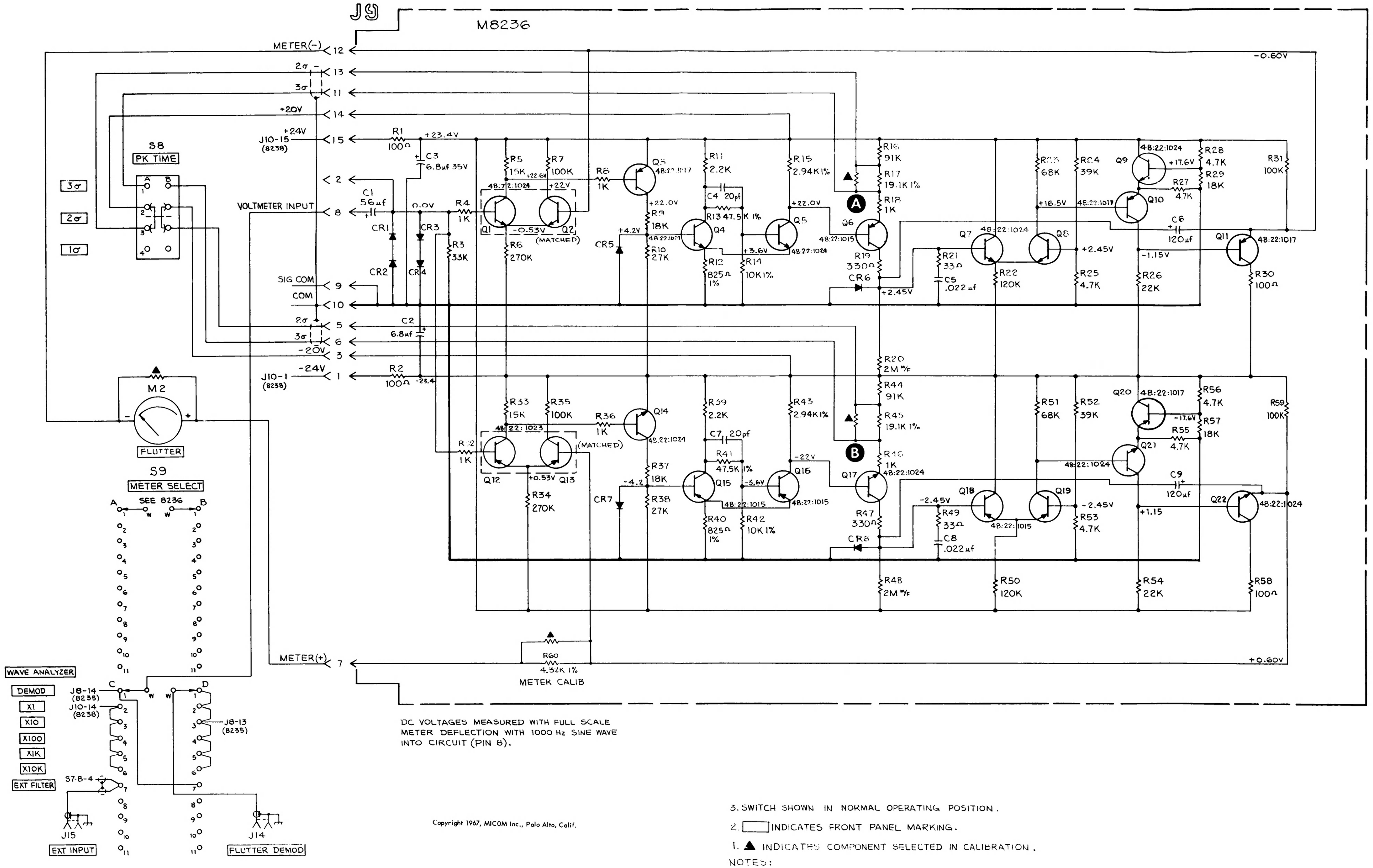


B

5V/div

A

200μ sec/div



DC VOLTAGES MEASURED WITH FULL SCALE METER DEFLECTION WITH 1000 Hz SINE WAVE INTO CIRCUIT (PIN 8).

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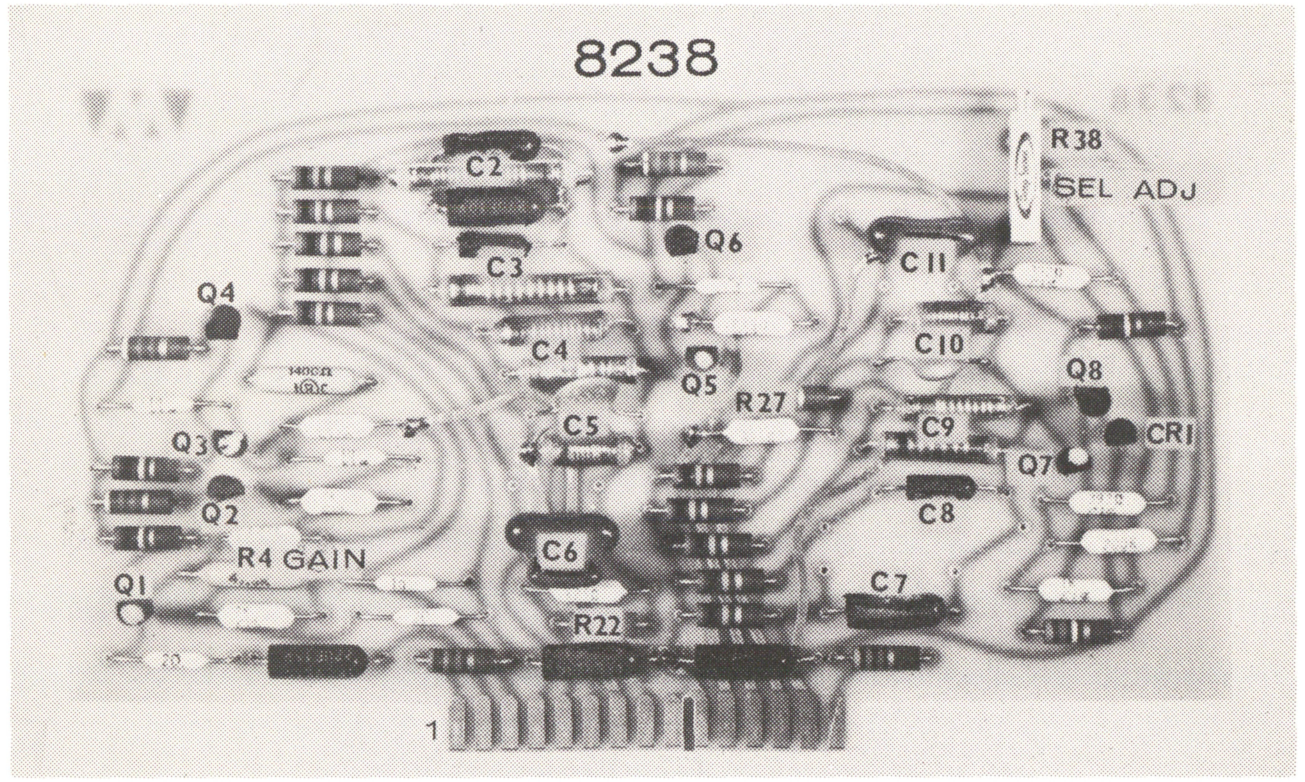
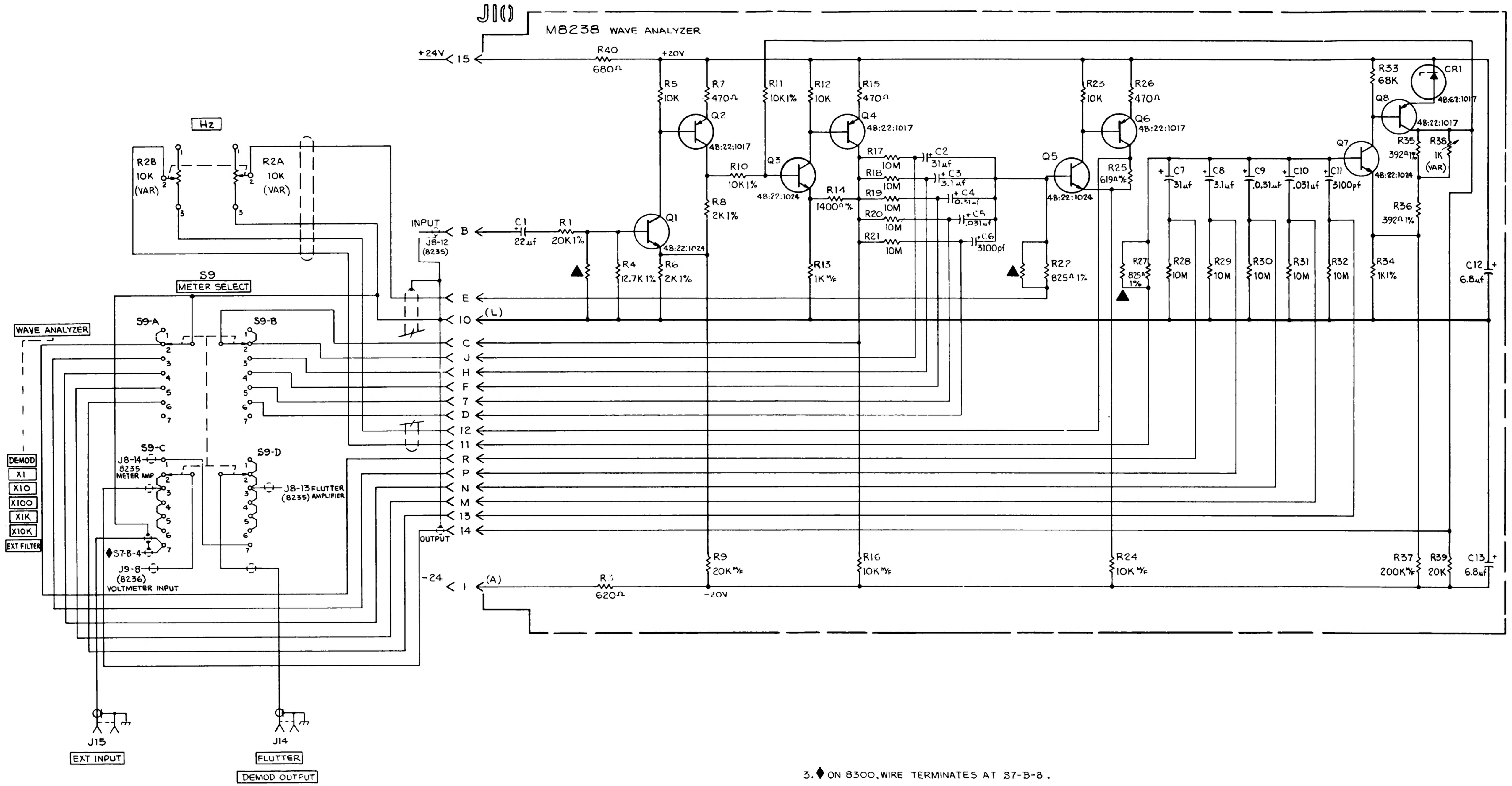
3. SWITCH SHOWN IN NORMAL OPERATING POSITION.
2. ☐ INDICATES FRONT PANEL MARKING.
1. ▲ INDICATES COMPONENT SELECTED IN CALIBRATION.
NOTES:

Figure 6 - 9 Card 8236

STATISTICAL PEAK VOLTMETER





NOTES:

1. ▲ INDICATES COMPONENT SELECTED IN CALIBRATION.

2. (VAR) INDICATES VARIABLE RESISTOR.

3. ♦ ON 8300, WIRE TERMINATES AT S7-B-8.

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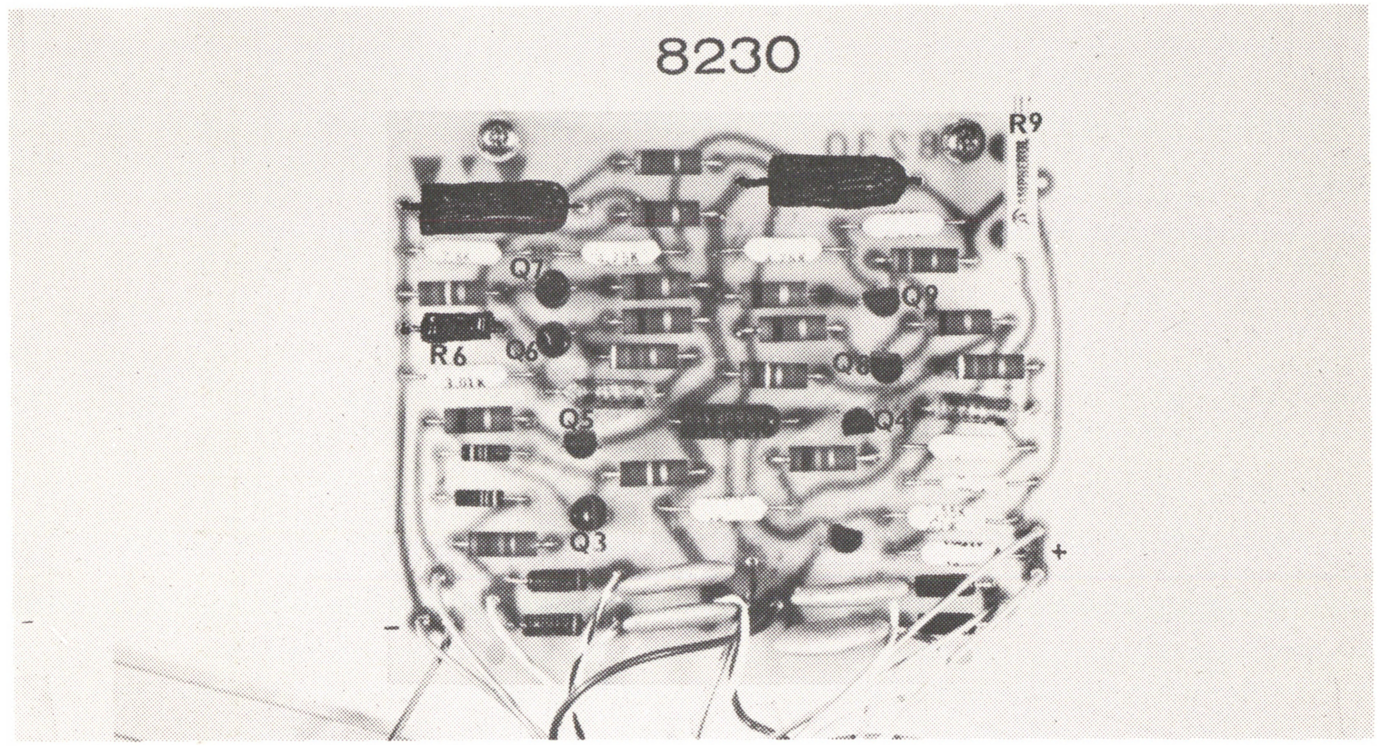
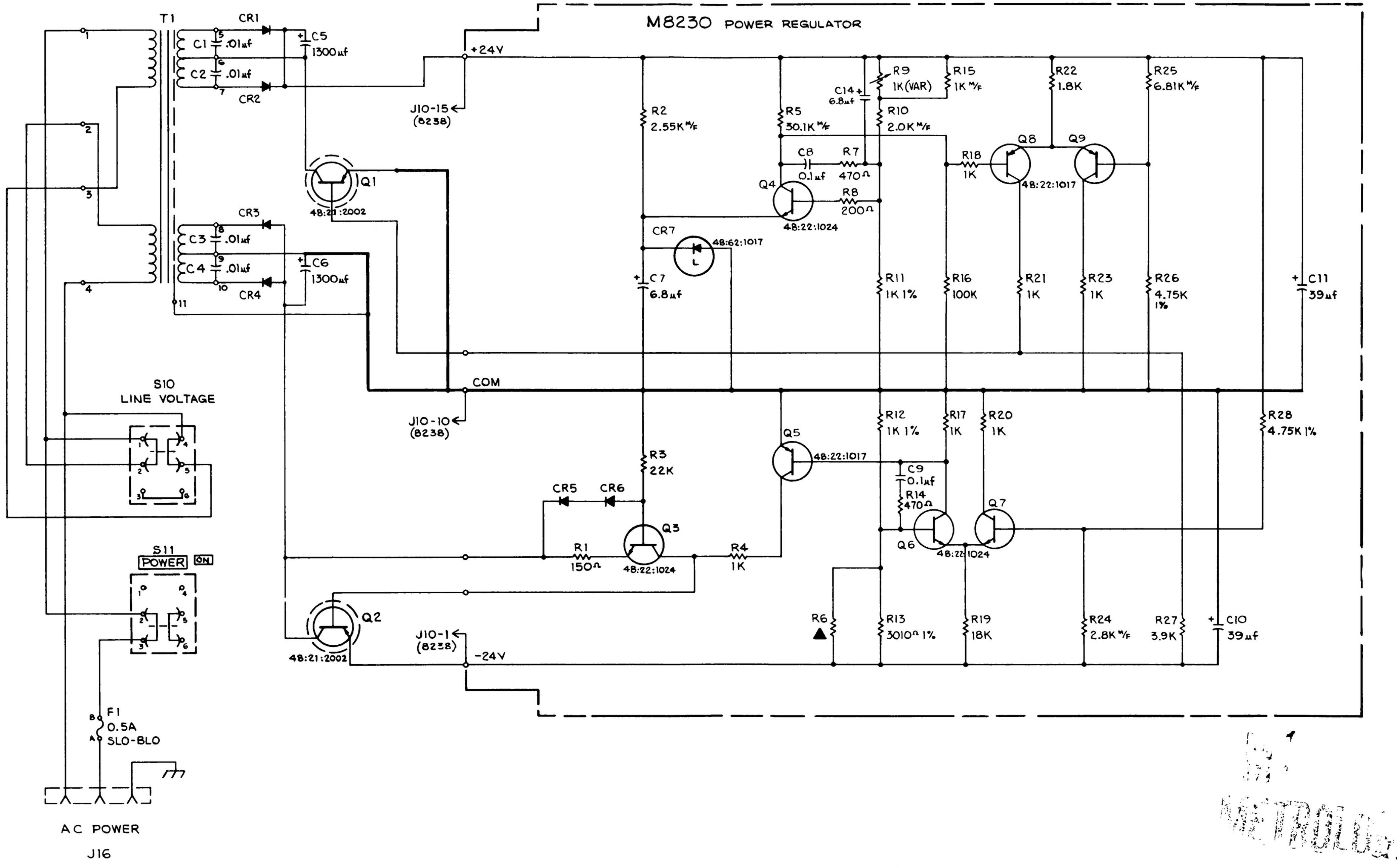
Figure 6 - 10 Card 8238

WAVE ANALYZER
(-W MODELS ONLY)





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4. ▭ INDICATES FRONT PANEL MARKING.

3. SWITCHES SHOWN IN NORMAL OPERATING POSITION.

2. BROKEN LINE ENCLOSING TRANSISTOR INDICATES COMPONENT MOUNTED ON HEAT SINK.

1. ▲ INDICATES COMPONENT SELECTED IN CALIBRATION.

NOTES:

Figure 6 - 11 Card 8230

REGULATED POWER SUPPLY

SECTION VII

TABLE OF REPLACEABLE PARTS

7-1 This section contains information for ordering replacement parts.

7-2 To obtain replacement parts, address order to:
MICOM, Inc.
855 Commercial Street
Palo Alto, California 94303

7-3 Specify the following information for each part:
a. Model and complete serial number of instrument
b. MICOM stock number
c. Circuit reference designator and description

For non-listed parts include model and serial number, description of the part, and function and location of the part.

REFERENCE DESIGNATORS

A = assembly	J = jack	R = resistor
C = capacitor	K = relay	S = switch
CR = diode	L = inductor	T = transformer
DS = lamp	M = meter	V = vacuum tube, photocell, etc.
F = fuse	MP = mechanical part	W = cable
FF = flip flop	P = plug	Y = crystal
FL = filter	Q = transistor	Z = network

ABBREVIATIONS

A	Ampere	al elect	aluminum electrolytic
dB	deciBel	cer	ceramic
F	Farad	comp	composition
H	Henry	FET	field effect transistor
Hz	Hertz - cycle per second	fxd	fixed
V	Volt	Ge	germanium
W	Watt	int cir	integrated circuit
		met flm	metal film
M	10^6	my	mylar
K	10^3	poly	polystyrene
D	10	poly c	polycarbonate
d	10^{-1}	Si	silicon
m	10^{-3}	sil mica	silver mica
μ	10^{-6}	Ta	tantalum
n	10^{-9}	var	variable
p	10^{-12}	ww	wirewound

Δ designates component selected in mfg - may be omitted

COMPANY ABBREVIATIONS

A	Arco	IRC	International Resistance Company
AB	Allen Bradley	KT	Kemet
ANL	Amphenol	MO	Motorola
B	Bourns	RA	Raytheon
CL	Clarostat	S	Sprague
CRL	Centralab	SC	Switchcraft
D	Dialco	SH	Siemens and Halske
EL	Electra Manufacturing Company	SY	Sylvania
EM	Electromotive Manufacturing Co.	TI	Texas Instruments
F	Fairchild	TRW	Thompson Ramo Woolridge
GE	General Electric	VK	Viking
GI	General Instrument		

Table 7-1. Replaceable Parts (Cont'd.)

SCHEMATIC REFERENCE	DESCRIPTION OR COMMERCIAL EQUIVALENT	MICOM STOCK NO.	TQ
Card 8237-1 TEST OSCILLATOR			
C1	C: fxd: sil mica 1000pF 5% DM-19	15:49:1025	1
C2	C: fxd: sil mica 6800pF 5% DM-19	15:49:6825	1
C3, C9, C10, C24	C: fxd: Ta 6.8μF 20% 35V	15:37:6857	4
C4	C: fxd: cer 2000pF 10%	15:19:2026	1
C5	C: fxd: cer 200pF 10%	15:19:2016	1
C6, C7, C8	C: fxd: cer 500pF 10%	15:19:5016	3
C11	C: fxd: sil mica 2000pF 5% DM-19	15:49:2025	1
C12	C: fxd: met my 0.68μF 10%	15:29:6846	1
C13, C15	C: fxd: met my 0.47μF 10%	15:29:4746	2
C14	C: fxd: cer 20pF 10%	15:19:2006	1
C16, C18	C: fxd: cer 100pF 10%	15:19:1016	2
C17	C: fxd: met my 0.068μF 20%	15:29:6837	1
C19, C20	C: fxd: cer 1000pF 10%	15:19:1026	2
C21, C22	C: fxd: cer 2000pF 10%	15:19:2026	2
C23, C25	C: fxd: cer 3900pF 10%	15:19:3926	2
C26, C27	C: fxd: cer 1000pF 10%	15:19:1026	2
C28, C29	C: fxd: cer 8000pF 10%	15:19:8026	2
C30, C31	C: fxd: met my 0.015μF 20%	15:29:1537	2
C32, C33	C: fxd: met my 0.033μF 20%	15:29:3337	2
CR1	diode Si breakdown GP 1N458A	48:12:1006	1
CR2, CR3	diode Si breakdown 6.5V ±10%	48:62:1017	2
FF1, FF2, FF3, FF4	integrated circuit dual JK flip flop MO MC790P	48:52:1016	4
J1	connector 15 pin double sided p.c. VK 2VK15/1AN-5	21:21:0915	1
J11	connector BNC UG657/U	21:25:0700	1
Q1, Q2, Q4, Q5, Q6, Q9, Q11, Q15, Q16, Q17	transistor: Si NPN planar MO MPS2925	48:22:1024	10
Q7, Q12	transistor: Si PNP planar MO MPS6519	48:22:1015	2
Q3, Q14	transistor: Si PNP planar MO MPS3638	48:22:1017	2
Q10	transistor: Si FET P type F 2N4360, Select 5Vco	48:22:1029	1
R1 thru R16	part of S1 Test Frequency sw. assy.		
R17	R: fxd: comp, 11K 5% 1/2W	47:22:1135	1
R18, R24	R: fxd: comp, 82K 5% 1/2W	47:22:8235	2
R19, R25, R54, R58, R59, R62, R68	R: fxd: comp, 10K 5% 1/2W	47:22:1035	7
R20, R28, R37, R75	R: fxd: comp, 4.7K 5% 1/2W	47:22:4725	4
R21, R23	R: fxd: comp, 2K 5% 1/2W	47:22:2025	2
R22, R63	R: fxd: comp, 6.8K 5% 1/2W	47:22:6825	2
R26, R27, R50, R52, R64, R80, R81	R: fxd: comp, 1K 5% 1/2W	47:22:1025	7
R29	R: fxd: comp, 47K 5% 1/2W	47:22:4735	1
R30, R31, R32, R33, R56, R57, R65, R66, R70, R71, R72, R73, R76, R77, R83, R84, R87, R91	R: fxd: comp, 3K 5% 1/2W	47:22:3025	18
R34, R39	R: fxd: met flm, 2K 1% 1/4W	47:11:2001	2
R35	R: fxd: met flm, 69.8K 1% 1/4W	47:11:6982	1
R36	R: fxd: met flm, 100K 1% 1/4W	47:11:1003	1
R38, R53	R: fxd: comp, 470 ohm 5% 1/2W	47:22:4715	2
R40, R55	R: fxd: comp, 100 ohm 5% 1/2W	47:22:1015	2
R41	R: fxd: comp, 20K 5% 1/2W	47:22:2035	1
R42, R60	R: fxd: comp, 3.3K 5% 1/2W	47:22:3325	2
R43, R46	R: fxd: comp, 1M 5% 1/2W	47:22:1055	2
R44	R: fxd: comp, 24K 5% 1/2W	47:22:2435	1
R45	R: fxd: comp, 33K 5% 1/2W	47:22:3335	1

Table 7-1. Replaceable Parts (Cont'd.)

SCHEMATIC REFERENCE	DESCRIPTION OR COMMERCIAL EQUIVALENT	MICOM STOCK NO.	TQ
R47	R: fxd: comp, 200K 5% 1/2W	47:22:2045	1
R48	R: fxd: comp, selected 100 ohm to 1K		1
R49, R61	R: fxd: comp, 3.9K 5% 1/2W	47:22:3925	2
R51	R: fxd: comp, 75K 5% 1/2W	47:22:7535	1
R67, R69	R: fxd: comp, 150K 5% 1/2W	47:22:1545	2
R74, R78, R88	R: fxd: comp, 22K 5% 1/2W	47:22:2235	3
R79	R: fxd: comp, 39K 5% 1/2W	47:22:3935	1
R82	R: fxd: met flm,681K 1% 1/4W	47:11:6813	1
R85	R: fxd: met flm, 1M 1% 1/4W	47:11:1004	1
R86, R92	R: fxd: comp, 68K 5% 1/2W	47:22:6835	2
R89	R: fxd: comp, 2.2K 5% 1/2W	47:22:2225	1
R90	R: fxd: ww, 150 ohm 12W	47:37:1511	1
S1	switch, rotary, test frequency switch assy.	51:78:0821	1
S2	switch, rotary, 2 pole, 3 position Sp. Ret. to center, Oak 399189-28	51:42:0321	1
Y1	216 kHz Quartz crystal	61:01:2163	1
Card 8239-1 BANDPASS FILTERS			
C1	C: fxd: met my .047μF 20%	15:29:4737	1
C2, C3	C: fxd: Ta 6.8μF 20% 35V	15:37:6857	2
C4	C: fxd: cer 6000pF 10%	15:19:6026	1
C5	C: fxd: Ta 3.3μF 20% 35V	15:37:3357	1
C6 thru C29	C: fxd: selected at assy. Nominal values on schematic		24
J2	connector 15 pin p.c. socket double sided 2VK15/1AN-2	21:21:0915	1
J12	connector BNC UG657/U	21:25:0700	1
L1, L2	L: fxd: 153mH 5%	18:23:1541	2
L3, L4	L: fxd: 77mH 5%	18:23:7735	2
L5, L6	L: fxd: 38mH 5%	18:23:3835	2
L7, L8	L: fxd: 19mH 5%	18:23:1935	2
L9, L10	L: fxd: 9.6mH 5%	18:23:9621	2
L11, L12	L: fxd: 4.8mH 5%	18:23:4821	2
L13, L14	L: fxd: 2.4mH 5%	18:23:2425	2
L15, L16	L: fxd: 760μH 5%	18:23:7615	2
Q1	transistor: FET P type selected F 2N4360	48:22:1030	1
Q2	transistor: Si NPN planar MO MPS2925	48:22:1024	1
Q3	transistor: Si PNP planar MO MPS6519	48:22:1015	1
R1, R4, R7	R: fxd: met flm, 1K 1% 1/4W	47:11:1001	3
R2, R9	R: fxd: met flm, 100K 1% 1/4W	47:11:1003	2
R3	R: fxd: comp, 6.8K 5% 1/2W	47:22:6825	1
R5	R: fxd: met flm, 10K 1% 1/4W	47:11:1002	1
R6	R: fxd: comp, 330 ohm 5% 1/2W	47:22:3315	1
R8	R: fxd: comp, 47K 5% 1/2W	47:22:4735	1
R10, R11	R: fxd: comp, 10K 5% 1/2W	47:22:1035	2
R12	R: fxd: met flm, 2K 1% 1/4W	47:11:2001	1
Card 8231A LIMITER-DOUBLER, SIGNAL LEVEL INDICATORS			
C1, C20	C: fxd: met my 0.1μF 10%	15:29:1045	2
C2, C3, C6, C8, C10, C11, C12, C13, C18, C19	C: fxd: Ta 6.8μF 20% 35V	15:37:6857	10
C4, C7, C15	C: fxd: met my 0.47μF 10%	15:29:4746	3
C5, C9	C: fxd: cer 20pF 10%	15:19:2006	2
C14	C: fxd: Ta 22μF 20% 15V	15:34:2267	1
C16, C17	C: fxd: cer 200pF 10%	15:19:2016	2
C21	C: fxd: Ta 4.7μF 20% 35V	15:37:4757	1
C22, C23	C: fxd: Ta 2.2μF 20% 35V	15:37:2257	2

Table 7-1. Replaceable Parts (Cont'd.)

SCHEMATIC REFERENCE	DESCRLPTION OR COMMERCIAL EQUIVALENT	MICOM STOCK NO.	TQ
CR1, CR2; CR3, CR4; CR5, CR6; CR7, CR8	diode Si fast recovery, matched pairs	48:72:1025	4 pr
CR9, CR10, CR11	diode Si GP 1N458A	48:12:1006	3
DS1, DS3	lamp 28V 40ma bipin amber	39:13:2840	2
DS2	lamp 28V 40ma bipin white	39:19:2840	1
J3	connector 15 pin p.c. single sided	21:21:0815	1
Q1, Q2, Q3, Q8, Q9, Q13, Q14, Q15, Q17, Q18	transistor: Si NPN planar MO MPS2925	48:22:1024	10
Q4, Q5, Q6, Q7	transistor: Si PNP planar MO MPS6519	48:22:1015	4
Q10, Q11, Q12, Q16	transistor: Si PNP planar MO MPS3638	48:22:1017	4
R1	R: fxd: met flm, 10K 1% 1/4W	47:11:1002	1
R2, R3	R: fxd: met flm, 100K 1% 1/4W	47:11:1003	2
R4	R: fxd: met flm, 2K 1% 1/4W	47:11:2001	1
R5, R10	R: fxd: met flm, 1K 1% 1/4W	47:11:1001	2
R6, R8	R: fxd: met flm, 46.4K 1% 1/4W	47:11:4642	2
R7, R11	R: fxd: comp, 47K 5% 1/2W	47:22:4735	2
R9, R24, R26, R34	R: fxd: comp, 1K 5% 1/2W	47:22:1025	4
R12, R18	R: fxd: comp, 2K 5% 1/2W	47:22:2025	2
R13, R14	R: fxd: comp, 91K 5% 1/2W	47:22:9135	2
R15	R: fxd: comp, 470K 5% 1/2W	47:22:4745	1
R16, R17	R: fxd: comp, 1.8K 5% 1/2W	47:22:1825	2
R19	R: fxd: comp, 3.6K 5% 1/2W	47:22:3625	1
R20	R: fxd: comp, 3.9K 5% 1/2W	47:22:3925	1
R21	R: fxd: met flm, 2.26K 1% 1/4W	47:11:2261	1
R22, R38, R43, R44, R46, R50, R54, R56	R: fxd: comp, 10K 5% 1/2W	47:22:1035	8
R23, R29	R: fxd: comp, 2.2K 5% 1/2W	47:22:2225	2
R25	R: fxd: met flm, 1.78K 1% 1/4W	47:11:1781	1
R27	R: fxd: met flm, 681K 1% 1/4W	47:11:6813	1
R28	R: fxd: comp, 1.2K 5% 1/2W	47:22:1225	1
R30	R: fxd: comp, 3.3K 5% 1/2W	47:22:3325	1
R31	R: fxd: met flm, 11.8K 1% 1/4W	47:11:1182	1
R32	R: fxd: met flm, 5.76K 1% 1/4W	47:11:5761	1
R33, R55	R: fxd: comp, 4.7K 5% 1/2W	47:22:4725	2
R35	R: fxd: comp, 15K 5% 1/2W	47:22:1535	1
R36	R: fxd: comp, 20K 5% 1/2W	47:22:2035	1
R37	R: fxd: comp, 100 ohm 5% 1/2W	47:22:1015	1
R39	R: fxd: comp, 220K 5% 1/2W	47:22:2245	1
R40	R: fxd: comp, 1M 5% 1/2W	47:22:1055	1
R41, R49	R: fxd: comp, 470 ohm 5% 1/2W	47:22:4715	2
R42, R45	R: fxd: comp, 6.2K 5% 1/2W	47:22:6225	2
R47	R: fxd: comp, 33 ohm 5% 1/2W	47:22:3305	1
R48	R: fxd: comp, 390 ohm 5% 1/2W	47:22:3915	1
R51	R: fxd: comp, 2.4K 5% 1/2W	47:22:2425	1
R52	R: fxd: comp, 12K 5% 1/2W	47:22:1235	1
R53	R: fxd: comp, 330 ohm 5% 1/2W	47:22:3315	1
Card 8232-1 PHASE LOCKED DOUBLERS			
C2, C10, C18, C25	C: fxd: cer 500pF 10%	15:19:5016	4
C3, C11, C51	C: fxd: cer 300pF 10%	15:37:3016	3
C4, C5	C: fxd: met my 0.015μF 20%	15:29:1537	2
C6, C14, C21, C30, C38, C46	C: fxd: cer 50pF 10%	15:19:5006	6
C7, C9, C15, C17, C22, C24, C26, C31, C33, C39, C41, C47, C49	C: fxd: cer 200pF 10%	15:19:2016	13

Table 7-1. Replaceable Parts (Cont'd.)

SCHEMATIC REFERENCE	DESCRIPTION OR COMMERCIAL EQUIVALENT	MICOM STOCK NO.	TQ
C8, C16, C23, C32, C34, C35, C40, C42, C43, C48	C: fxd: cer 100pF 10%	15:19:1016	10
C12, C13	C: fxd: cer 6000pF 10%	15:19:6026	2
C19, C20	C: fxd: cer 5000pF 10%	15:19:5021	2
C27, C50	C: fxd: Ta 6.8μF 20% 35V	15:37:6857	2
C28, C29	C: fxd: cer 2000pF 10%	15:19:2026	2
C36, C37	C: fxd: cer 1000pF 10%	15:19:1026	2
C44, C45	C: fxd: cer 500pF 10%	15:19:5016	2
CR1	diode Si breakdown 6.5V ± 10%	48:62:1017	1
CR2, CR3, CR4, CR5, CR6, CR7, CR8, CR9, CR10, CR11, CR12, CR13	diode Si fast recovery 1N3064	48:12:1005	12
J4	connector 15 pin p.c. single sided 2VK15S/1-2	21:21:0815	1
Q2, Q5, Q6, Q9, Q12, Q13, Q16, Q19, Q20, Q23, Q26, Q27, Q30, Q33, Q34, Q37, Q40, Q41	transistor: Si PNP planar MO MPS3638	48:22:1017	18
Q3, Q4, Q7, Q8, Q10, Q11 Q14, Q15, Q17, Q18, Q21, Q22, Q24, Q25, Q28, Q29, Q31, Q32, Q35, Q36, Q38, Q39, Q42, Q43	transistor: Si NPN planar MO MPS2925	48:22:1024	24
R2	R: fxd: comp, 2.7K 5% 1/2W	47:22:2725	1
R4, R12, R13, R16 R17, R25, R26, R29, R30, R37, R39, R42, R44, R52, R53, R56, R57, R65, R66, R69, R70, R78, R79, R82	R: fxd: comp, 1K 5% 1/2W	47:22:1025	25
R5, R18, R31, R45, R58, R71	R: fxd: comp, 22K 5% 1/2W	47:22:2235	6
R6, R19, R32, R46, R59, R72	R: fxd: met flm, 40.2K 1% 1/4W	47:11:4022	6
R7, R20	R: fxd: comp, 10 ohm 5% 1/2W	47:22:1005	2
R8, R21, R34, R48, R61, R74	R: fxd: met flm, 20K 1% 1/4W	47:11:2002	6
R9, R10, R22, R23, R35, R36, R49, R50, R62, R63, R75, R76	R: fxd: comp, 6.8K 5% 1/2W	47:22:6825	12
R11, R14, R15, R24, R27, R28 R38, R40, R41, R51, R54, R55, R64, R67, R68, R77, R80, R81	R: fxd: comp, 4.7K 5% 1/2W	47:22:4725	17
R33, R47, R60, R73	R: fxd: comp, 47 ohm 5% 1/2W	47:22:4705	4
R43	R: fxd: comp, 100 ohm 5% 1/2W	47:22:1015	1
R83	R: var: ww, 2K 15T screwdriver	47:53:2021	1
Card 8233 QCG DEMODULATOR-DRIFT AMPLIFIER			
C1, C3	C: fxd: cer 100pF 10%	15:19:1016	2
C2, C4, C10, C11	C: fxd: Ta 6.8μF 20% 35V	15:37:6857	4
C5	C: fxd: sil mica 100pF 5%	15:49:1015	1
C6	C: fxd: met my 0.01μF 20%	15:29:1037	1
C7	C: fxd: sil mica 24pF 5%	15:49:2405	1
C8	C: fxd: sil mica 200pF 5%	15:49:2015	1
C9	C: var: cer 9 - 50pF	15:59:500Y	1
C12	C: fxd: cer 6000pF 10%	15:19:6026	1
C13, C14	C: fxd: cer 300pF 10%	15:19:3016	2
C15, C16, C21, C22	C: fxd: Ta 8.2μF 20% 20V	15:35:8257	4
C17, C18	C: fxd: Ta 56μ F 20% 6V	15:32:5667	2
C19, C20	C: fxd: met my 0.022μF 20%	15:29:2237	2
C23	C: fxd: met my 0.047μF 20%	15:29:4737	1

Table 7-1. Replaceable Parts (Cont.)

SCHEMATIC REFERENCE	DESCRIPTION OR COMMERCIAL EQUIVALENT	MICOM STOCK NO.	TQ
C24	C: fxd: **Ta** 4.7μF 20% (on J13)	15:35:4757	1
CR1, CR2	part of S3 assy.		
CR3, CR4, CR5, CR6, CR7 CR8, CR9, CR11, CR12	diode Si fast recovery GE 1N3064	48:12:1005	9
CR10	diode Si breakdown 6.5V ± 10%	48:62:1017	1
J5	connector 15 pin p.c. single sided 2VK15S/1-2	21:21:0815	1
J13	connector BNC UG657/U	21:25:0700	1
L1	inductor: fxd: 10mH ±5%	18:23:1035	1
M1	meter: 50-0-50 μ A DC 4"	29:31:2001	1
Q1, Q2, Q3, Q5, Q13, Q14, Q15	transistor: Si PNP planar MO MPS3638	48:22:1017	7
Q4, Q6, Q8, Q11, Q12, Q16	transistor: Si NPN planar MO MPS2925	48:22:1024	6
Q7	transistor: Si PNP high gain MO MPS6519	48:22:1015	1
Q9, Q10	transistor: Si NPN matched pair	48:72:1024	1
R1 thru R18	part of S3 assy.		
R19, R31	R: fxd: comp, 270 ohm 5% 1/2W	47:22:2715	2
R20	R: fxd: comp, 1K 5% 1/2W	47:22:1025	1
R21	R: fxd: comp, 200K 5% 1/2W	47:22:2045	1
R22, R41	R: fxd: comp, 2.2K 5% 1/2W	47:22:2225	2
R23, R65, R67	R: fxd: comp, 8.2K 5% 1/2W	47:22:8225	3
R24, R32	R: fxd: comp, 3.3K 5% 1/2W	47:22:3325	2
R25, R26, R36	R: fxd: comp, 9.1K 5% 1/2W	47:22:9125	3
R27	R: fxd: comp, 3.9K 5% 1/2W	47:22:3925	1
R28	R: fxd: comp, 33K 5% 1/2W	47:22:3335	1
R29	R: fxd: comp, 68K 5% 1/2W	47:22:6835	1
R30	R: fxd: met flm, 3.83K 1% 1/4W	47:11:3831	1
R33	R: fxd: comp, 4.3K 5% 1/2W	47:22:4325	1
R34, R43, R77	R: fxd: met flm, 1K 1% 1/4W	47:11:1001	3
R35, R66	R: fxd: comp, 1.5K 5% 1/2W	47:22:1525	2
R37	R: fxd: met flm, 15K 1% 1/4W	47:11:1502	1
R38, R44	R: fxd: met flm, 2.55K 1% 1/4W	47:11:2551	2
R39, R40	R: fxd: comp, 47 ohm 5% 1/2W	47:22:4705	2
R42, R68	R: fxd: comp, 6.2K 5% 1/2W	47:22:6225	2
R47 thru R51	part of S4 assy.		
R52	R: fxd: met flm, 2.49K 1% 1/4W	47:11:2491	1
R53, R72	R: fxd: comp, 100 ohm 5% 1/2W	47:22:1015	2
R54, R55, R56	R: fxd: met flm, 1M 1% 1/4W	47:11:1004	3
R57	R: fxd: comp, 2.4K 5% 1/2W	47:22:2425	1
R58, R62	R: fxd: met flm, 681K 1% 1/4W	47:11:6813	2
R59, R61	R: fxd: comp, 43K 5% 1/2W	47:22:4335	2
R60	R: fxd: comp, 240K 5% 1/2W	47:22:2445	1
R63, R69	R: fxd: comp, 100K 5% 1/2W	47:22:1045	2
R64	R: fxd: comp, 2K 5% 1/2W	47:22:2025	1
R70	R: fxd: met flm, 60.4K 1% 1/4W	47:11:6042	1
R71	R: fxd: met flm, 59K 1% 1/4W	47:11:5942	1
R73, R74, R75	R: fxd: met flm, 30.1K 1% 1/4W	47:11:3012	3
R78, R81	R: fxd: comp, 15K 5% 1/2W	47:22:1535	2
R79, R80	R: fxd: comp, 10K 5% 1/2W	47:22:1035	2
S3	Zero Set assy. (includes R1 thru R18 and CR1)	51:72:1105	1
S4	Drift Range assy. (includes R47 thru R51)	51:72:0602	1
S5	Slide switch 4 pole 3 position	51:24:0313	1

Table 7-1. Replaceable Parts (Cont'd.)

SCHEMATIC REFERENCE	DESCRIPTION OR COMMERCIAL EQUIVALENT	MICOM STOCK NO.	TQ
Card 8234-1 FLUTTER BANDWIDTH FILTERS			
C1, C2	C: fxd: Ta 6.8μF 20% 35V	15:37:6857	2
C3, C4	C: fxd: Ta 120μF 20% 6V	15:32:1277	2
C5, C6, C7, C8, C10, C12, C13, C14, C15, C16, C18, C20, C21, C22, C23, C24, C26, C28	Selected at assy. nominal values shown on schematic		
J6	connector 15 pin p.c. single sided 2VK15S/1-2	21:21:0815	1
Q1, Q3, Q6, Q7, Q10, Q11, Q14	transistor: Si NPN planar MO MPS2925	48:22:1024	7
Q4, Q5, Q8, Q9, Q12, Q13	transistor: Si PNP planar MO MPS6523	48:22:1029	6
Q2	transistor: Si PNP planar MO MPS6519	48:22:1015	1
R1, R2, R3	R: fxd: met flm, 10K 1% 1/4W	47:11:1002	3
R4	R: fxd: met flm, 3.32K 1% 1/4W	47:11:3321	1
R5	R: fxd: comp, 430 ohm 5% 1/2W	47:22:4315	1
R6	R: fxd: comp, 750 ohm 5% 1/2W		
R7, R22, R37	R: fxd: met flm, 2.55K 1% 1/4W	47:11:2551	3
R8, R17, R23, R32, R38, R47	R: fxd: met flm, 4.75K 1% 1/4W	47:11:4751	6
R9, R24, R39	R: fxd: comp, 1M 5% 1/2W	47:22:1055	3
R10, R25, R40	R: fxd: met flm, 20K 1% 1/4W	47:11:2002	3
R11, R21, R26, R36, R41, R51	R: fxd: comp, 47 ohm 5% 1/2W	47:22:4705	6
R12, R27, R42	R: fxd: met flm, 6.49K 1% 1/4W	47:11:6491	3
R13, R28, R43	R: fxd: met flm, 5.11K 1% 1/4W	47:11:5111	3
R14, R15, R29, R30, R44, R45	R: fxd: met flm, 1K 1% 1/4W	47:11:1001	6
R18, R33, R48	R: fxd: met flm, 15K 1% 1/4W	47:11:1502	3
R19, R20, R34, R35, R49, R50	R: fxd: met flm, 3.01K 1% 1/4W	47:11:3011	6
S7	switch, rotary, 2 pole 8 position	51:72:0813	1
Card 8334 FLUTTER BANDWIDTH FILTERS			
C1 thru C24	selected at assy. nominal values on schematic		
J7	connec tor 15 pin p.c. single sided 2VK15S/1-2	21:21:0815	1
Q1, Q4, Q5, Q8, Q9, Q12, Q13, Q16	transistor: Si NPN planar MO MPS2925	48:22:1024	8
Q2, Q3, Q6, Q7, Q10, Q11, Q14, Q15	transistor: Si PNP planar MO MPS6523	48:22:1029	8
R1, R15, R29, R43	R: fxd: met flm, 2.55K 1% 1/4W	47:11:2551	4
R2, R10, R16, R24, R30, R38, R44, R52	R: fxd: met flm, 4.75K 1% 1/4W	47:11:4751	8
R3, R17, R31, R45	R: fxd: comp, 1M 5% 1/2W	47:22:1055	4
R4, R18, R32, R46	R: fxd: met flm, 20K 1% 1/4W	47:11:2002	4
R5, R14, R19, R28, R33, R42, R47, R56	R: fxd: comp, 47 ohm 5% 1/2W	47:22:4705	8
R6, R20, R34, R48	R: fxd: met flm, 6.49K 1% 1/4W	47:11:6491	4
R7, R21, R35, R49	R: fxd: met flm, 5.11K 1% 1/4W	47:11:5111	4
R8, R9, R22, R23, R36, R37, R50, R51	R: fxd: met flm, 1K 1% 1/4W	47:11:1001	8
R11, R25, R39, R53	R: fxd: met flm, 15K 1% 1/4W	47:11:1500	4
R12, R13, R26, R27, R40, R41, R54, R55	R: fxd: met flm, 3.01K 1% 1/4W	47:11:3011	8

Table 7-1. Replaceable Parts (Cont'd.)

SCHEMATIC REFERENCE	DESCRIPTION OR COMMERCIAL EQUIVALENT	MICOM STOCK NO.	TQ
Card 8235 FLUTTER AMPLIFIER			
C1	C: fxd: Ta 22μF 20% 15V	15:34:2267	1
C2, C3, C5	C: fxd: Ta 6.8μF 20% 35V	15:37:6857	3
C4	C: fxd: Ta 330μF 20% 6V	15:32:3377	1
C6	C: fxd: cer 20pF 10%	15:19:2006	1
C7	C: fxd: cer 6000pF 10%	15:19:6026	1
C8	C: fxd: cer 1000pF 10%	15:19:1026	1
C9	C: fxd: Ta 56μF 20% 6V	15:32:5667	1
CR1, CR3	diode Si breakdown 6.5V ± 10%	48:62:1017	2
CR2	diode Si GP 1N458A	48:12:1006	1
J8	connector 15 pin p.c. single sided 2VK15S/1-2	21:21:0815	1
J14	connector BNC UG657/U	21:25:0700	1
Q1, Q2	FET matched Si p type	48:72:1031	1 pr
Q3, Q5, Q7	transistor: Si NPN planar MO MPS2925	48:22:1024	3
Q6	transistor: Si PNP planar MO MPS 3638	48:22:1017	1
Q8	transistor: Si PNP planar MO MPS 6519	48:22:1015	1
R1 thru R8	part of S6 assy.		
R9, R14	R: fxd: comp, 1.2K 5% 1/2W	47:22:1225	2
R10, R16	R: fxd: comp, 100 ohm 5% 1/2W	47:22:1015	2
R11	R: fxd: met flm, 100K 1% 1/4W	47:11:1003	1
R12	R: fxd: met flm, 28K 1% 1/4W	47:11:2802	1
R13	R: fxd: met flm, 46.4K 1% 1/4W	47:11:4642	1
R15	R: fxd: met flm, 249K 1% 1/4W	47:11:2493	1
R17	R: fxd: met flm, 20K 1% 1/4W	47:11:2002	1
R18, R22	R: fxd: comp, 20K 5% 1/2W	47:22:2035	2
R19	R: fxd: comp, 1.5K 5% 1/2W	47:22:1525	1
R20	R: fxd: comp, 3K 5% 1/2W	47:22:3025	1
R21	R: fxd: comp, 15K 5% 1/2W	47:22:1535	1
R23, R29	R: fxd: comp, 1K 5% 1/2W	47:22:1025	2
R24	R: fxd: comp, 33K 5% 1/2W	47:22:3335	1
R25	R: fxd: comp, 3.9K 5% 1/2W	47:22:3925	1
R26	R: fxd: comp, 68K 5% 1/2W	47:22:6835	1
R27	R: fxd: met flm, 1K 1% 1/4W	47:11:1001	1
R28	R: fxd: met flm, 11K 1% 1/4W	47:11:1102	1
R30	R: fxd: comp, 4.7K 5% 1/2W	47:22:4725	1
S6	Flutter Range Sw. assy.	51:72:0704	1
Card 8236 STATISTICAL PEAK VOLTMETER			
C1	C: fxd: Ta 56μF 20% 6V	15:32:5667	1
C2, C3	C: fxd: Ta 6.8μF 20% 35V	15:37:6857	2
C4, C7	C: fxd: cer 20pF 10%	15:19:2006	2
C5, C8	C: fxd: met my 0.022pF 20%	15:29:2237	2
C6, C9	C: fxd: Ta 120μF 20% 10V	15:33:1277	2
CR1, CR2, CR3, CR4	diode Si GP 1N458A	48:12:1006	4
CR5, CR6, CR7, CR8	diode Si fast recovery 1N3064	48:12:1025	4
J9	connector 15 pin p.c. single sided 2VK15S/1-2	21:21:0815	1
M2	meter: 0-200μA DC V.U. dynamics	29:31:1002	1
Q1, Q2	transistor: Si matched pair	48:72:1024	1 pr
Q3, Q10, Q11, Q20	transistor: Si PNP MO MPS3638	48:22:1017	4

Table 7-1. Replaceable Parts (Cont'd.)

SCHEMATIC REFERENCE	DESCRIPTION OR COMMERCIAL EQUIVALENT	MICOM STOCK NO.	TQ
Q4, Q5, Q7, Q8, Q9, Q14, Q17, Q21, Q22	transistor: Si NPN planar MO MPS2925	48:22:1024	9
Q6, Q15, Q16, Q18, Q19	transistor: Si PNP planar MO MPS6519	48:22:1015	5
Q12, Q13	transistor: matched pair	48:72:1023	1 pr
R1, R2, R30, R58	R: fxd: comp, 100 ohm 5% 1/2W	47:22:1015	4
R3	R: fxd: comp, 33K 5% 1/2W	47:22:3335	1
R4, R8, R18, R32, R36, R46	R: fxd: comp, 1K 5% 1/2W	47:22:1025	6
R5, R33	R: fxd: comp, 15K 5% 1/2W	47:22:1535	2
R6, R34	R: fxd: comp, 270K 5% 1/2W	47:22:2745	2
R7, R31, R35, R59	R: fxd: comp, 100K 5% 1/2W	47:22:1045	4
R9, R37	R: fxd: comp, 18K 5% 1/2W	47:22:1835	2
R10, R38	R: fxd: comp, 27K 5% 1/2W	47:22:2735	2
R11, R39	R: fxd: comp, 2.2K 5% 1/2W	47:22:2225	2
R12, R40	R: fxd: met flm, 825 ohm 1% 1/4W	47:11:8250	2
R13, R41	R: fxd: met flm, 47.5K 1% 1/4W	47:11:4752	2
R14, R42	R: fxd: met flm, 10K 1% 1/4W	47:11:1002	2
R15, R43	R: fxd: met flm, 2.94K 1% 1/4W	47:11:2941	2
R16, R44	R: fxd: comp, 91K 5% 1/2W	47:22:9135	2
R17, R45	R: fxd: met flm, 19.1K 1% 1/4W	47:11:1912	2
R19, R47	R: fxd: comp, 330 ohm 5% 1/2W	47:22:3315	2
R20, R48	R: fxd: met flm, 2M 1% 1/4W	47:11:2004	2
R21, R49	R: fxd: comp, 33 ohm 5% 1/2W	47:22:3305	2
R22, R50	R: fxd: comp, 120K 5% 1/2W	47:22:1245	2
R23, R51	R: fxd: comp, 68K 5% 1/2W	47:22:6835	2
R24, R52	R: fxd: comp, 39K 5% 1/2W	47:22:3935	2
R25, R27, R28, R53, R55, R56	R: fxd: comp, 4.7K 5% 1/2W	47:22:4725	6
R26, R54	R: fxd: comp, 22K 5% 1/2W	47:22:2235	2
R29, R57	R: fxd: comp, 18K 5% 1/2W	47:22:1835	2
R60	R: fxd: met flm, 4.32K 1% 1/4W	47:11:4321	
S8	switch, slide, 3 pole 3 position	51:24:0313	1
Card 8238 WAVE ANALYZER (-W MODELS ONLY)			
C1	C: fxd: Ta 22μ F 20% 10V	15:33:2267	1
C2, C7	C: fxd: Ta 31μ F 1% matched pair	15:34:3161	2
C3, C8	C: fxd: Ta 3.1μF 1% matched pair	15:96:3151	2
C4, C9	C: fxd: met my 0.31μF 1% matched pair	15:99:3141	2
C5, C10	C: fxd: met my 0.031μF 1% matched pair	15:99:3131	2
C6, C11	C: fxd: sil mica 3100pF 1% matched pair	15:99:3121	2
C12, C13	C: fxd: Ta 6.8μF 20% 35V	15:37:6857	2
CR1	diode Si breakdown 6.5V ± 10%	48:62:1017	1
J10	connector 15 pin p.c. double sided 2VK15/1AN-5	21:21:0915	1
J15	connector BNC UG657/U	21:25:0700	1
Q1, Q3, Q5, Q7	transistor: Si NPN planar MO MPS2925	48:22:1024	4
Q2, Q4, Q6, Q8	transistor: Si PNP planar MO MPS3638	48:22:1017	4
R1, R9	R: fxd: met flm, 20K 1% 1/4W	47:11:2003	2
R2A, R2B	R: var: Special ganged WW potentiometer	47:9A:103A	1
R3	R: fxd: comp, 620 ohm 5% 1/2W	47:22:6215	1
R4	R: fxd: met flm, 12.7K 1% 1/4W	47:11:1272	1
R5, R12, R23	R: fxd: comp, 10K 5% 1/2W	47:22:1035	3
R6, R8	R: fxd: met flm, 2K 1% 1/4W	47:11:2001	2

Table 7-1. Replaceable Parts (Cont'd.)

SCHEMATIC REFERENCE	DESCRIPTION OR COMMERCIAL EQUIVALENT	MICOM STOCK NO.	TQ
R7, R15, R26	R: fxd: comp, 470 ohm 5% 1/2W	47:22:4715	3
R10, R11, R16, R24	R: fxd: met flm, 10K 1% 1/4W	47:11:1002	4
R13, R34	R: fxd: met flm, 1K 1% 1/4W	47:11:1001	2
R14	R: fxd: met flm, 1.4K 1% 1/4W	47:11:1401	1
R17, R18, R19, R20, R21, R28, R29, R30, R31, R32	R: fxd: comp, 10M 5% 1/2W	47:22:1065	10
R22, R27	R: fxd: met flm, 825 ohm 1% 1/4W	47:11:8250	2
R25	R: fxd: met flm, 619 ohm 1% 1/4W	47:11:6190	1
R33	R: fxd: comp, 68K 5% 1/2W	47:22:6835	1
R35, R36	R: fxd: met flm, 392 ohm 1% 1/4W	47:11:3920	2
R37	R: fxd: met flm, 200K 1% 1/4W	47:11:2003	1
R38	R: var: WW 1K screwdriver	47:53:1025	1
R39	R: fxd: comp, 20K 5% 1/2W	47:22:2035	1
R40	R: fxd: comp, 680 ohm 5% 1/2W	47:22:6845	1
S9	switch, rotary, 4 pole 7 position	51:44:0718	1
Card 8230 REGULATED POWER SUPPLY			
C1, C2, C3, C4	C: fxd: cer, 0.01μF GMV	15:37:1039	4
C5, C6	C: fxd: Al elect, 1300μ F 50V	15:78:1387	2
C7, C14	C: fxd: Ta 6.8μF 20% 35V	15:37:6857	2
C8, C9	C: fxd: met my 0.1μ F 10%	15:29:1046	2
C10, C11	C: fxd: Ta 39μ F 20% 35V	15:37:3967	2
CR1, CR2, CR3, CR4	diode Si power 1N4383	48:12:2013	4
CR5, CR6	diode Si GP 1N458A	48:12:1006	2
CR7	diode Si breakdown 6.5V ± 10%	48:62:1017	1
F1	fuse: 1/2A slo blow 3AG-	51:12:0050	1
J6	connector AC 3 pin male power	21:14:0603	1
Q1, Q2	transistor: Ge power MO 2N376A	48:21:2002	2
Q3, Q4, Q6, Q7	transistor: Si NPN planar MO MPS2925	48:22:1024	4
Q5, Q8, Q9	transistor: Si PNP planar MO MPS3638	48:22:1017	3
R1	R: fxd: comp, 150 ohm 5% 1/2W	47:22:1515	1
R2	R: fxd: met flm, 2.55K 1% 1/4W	47:11:2551	1
R3	R: fxd: comp, 22K 5% 1/2W	47:22:2235	1
R4, R17, R18, R20, R21, R23	R: fxd: comp, 1K 5% 1/2W	47:22:1025	6
R5	R: fxd: met flm, 30.1K 1% 1/4W	47:11:3012	1
R6	R: fxd: selected		
R7, R14	R: fxd: comp, 470 ohm 5% 1/2W	47:22:4715	2
R8	R: fxd: comp, 200 ohm 5% 1/2W	47:22:2015	1
R9	R: var: WW 1K	47:53:1025	1
R10	R: fxd: met flm, 2K 1% 1/4W	47:11:2001	1
R11, R12, R15	R: fxd: met flm, 1K 1% 1/4W	47:11:1001	3
R13	R: fxd: met flm, 3.01K 1% 1/4W	47:11:3011	1
R16	R: fxd: comp, 100K 5% 1/2W	47:22:1045	1
R19	R: fxd: comp, 18K 5% 1/2W	47:22:1835	1
R22	R: fxd: comp, 1.8K 5% 1/2W	47:22:1825	1
R24	R: fxd: met flm, 2.8K 1% 1/4W	47:11:2801	1
R25	R: fxd: met flm, 6.81K 1% 1/4W	47:11:6811	1
R26, R28	R: fxd: met flm, 4.75K 1% 1/4W	47:11:4751	2
R27	R: fxd: comp, 3.9K 5% 1/2W	47:22:3925	1
S10	switch, slide 2P2T 115-230V	51:22:0201	1
S11	switch, rocker 2P1T power switch	51:52:0202	1
T1	transformer: Power 115-230V pri.	56:11:1254	1
	fuse holder AGC 1/4 x 1-1/4"		1

Table 7-1. Replaceable Parts (Cont'd.)

SCHEMATIC REFERENCE	DESCRIPTION OR COMMERCIAL EQUIVALENT	MICOM STOCK NO.	TQ
CHASSIS COMPONENTS			
	clip: #6-32 screw Tinnerman C6452-632	28:72:7602	16
	clip: #4-40 screw Tinnerman C7795-44027	28:72:7601	2
	clip: Tinnerman bipin lamp holder	21:29:1100	3
	side casting, left	14:12:0004	1
	side casting, right	14:12:0005	1
	knob, switch, bar RA DS70B-1-2G	24:22:0005	5
	knob, switch, round RA DS70-1BD-2G	24:22:0006	1
	dial, zero set, inner	24:13:1401	1
	dial, zero set, vernier	24:13:1404	1
	dial, Wave Analyzer	24:13:1402	1
	meter bezel	14:13:0001	
	feet, rubber	28:87:0001	4
	cover, top	14:11:0002	1
	cover, bottom	14:11:0003	1
	screws, rack mounting 10-32 x 2" Phillips, fillister head	28:11:2118	4
	screws, side casting mounting #8 x 1-1/4" sheet metal Phillips, oval head	28:12:4814	2
	socket, bipin lamp	21:26:1000	3
	power cord, Type SVT 8' #18-3, Belden #17258-S	60:5X:0002	1